

## Task 3: Petroleum Reduction Options

STAFF DRAFT REPORT

### Disclaimer

This report was prepared by the staffs of the California Energy Commission and California Air Resources Board. Opinions, conclusions and findings expressed in this report are those of the authors. The report does not represent the official position of the Energy Commission or the California Air Resources Board. This staff draft report is a compilation of the preliminary results based on objective technical staff analyses of the status of technologies, their relative petroleum reduction impacts and costs. The report presents a range of possible costs and impacts from an illustrative group of options. The cost and benefit calculations contained in these analyses do not yet account for environmental impacts (which will be included at a later time). These preliminary results should not be construed as indicating policy preference for a particular technology or strategy.

MARCH 2002  
P600-02-011D



Gray Davis, Governor

## Disclaimer

This report was prepared by the staffs of the California Energy Commission and California Air Resources Board. Opinions, conclusions and findings expressed in this report are those of the authors. The report does not represent the official position of the Energy Commission or the California Air Resources Board. This staff draft report is a compilation of the preliminary results based on objective technical staff analyses of the status of technologies, their relative petroleum reduction impacts and costs. The report presents a range of possible costs and impacts from an illustrative group of options. The cost and benefit calculations contained in these analyses do not yet account for environmental impacts (which will be included at a later time). These preliminary results should not be construed as indicating policy preference for a particular technology or strategy.

## Schedule

**Note to Reviewers and Stakeholders:** Initial comments on this Staff Report are requested at the March 28 public workshop. At that workshop, there will be a discussion of the overall schedule for the completion of this report. In addition, there will be other opportunities for public comment, including the April 15 planned public hearing.

## **ACKNOWLEDGEMENTS**

### **Energy Commission Contributing Staff**

McKinley Addy  
David Ashuckian  
Gerry Bemis  
Bill Blackburn  
Dan Fong  
Chris Kavalec  
Tom MacDonald  
Mike McCormack  
Jim Page  
Leigh Stamets  
Sherry Stoner  
Gary Yowell

### **Air Resources Board Contributing Staff**

Fereidun Feizollahi  
Chang Seung  
Chuck Shulock

### **Primary Consultants**

Mike Jackson, A.D. Little  
Nalu Kaahaaina, A.D. Little  
Paul Wuebben, South Coast Air Quality Management District

### **Management**

Cynthia Praul, Assistant Executive Director, Energy Commission  
Tom Cackette, Chief Deputy Executive Officer, Air Resources Board  
Nancy J. Deller, Deputy Director, Transportation Energy Division, Energy Commission  
Susan Brown, Manager, Transportation Technology Office, Energy Commission  
Pat Perez, Manager, Transportation Fuels Office, Energy Commission

## TABLE OF CONTENTS

	Page
Introduction.....	
Methodology for Evaluating Petroleum Reduction Options .....	
1. Fuel Efficiency Options	
Option 1A: Improved Vehicle Fuel Economy .....	
Option 1B: Fuel-Efficient Replacement Tires and Tire Inflation .....	
Option 1C: Government Fleets .....	
Option 1D: Vehicle Maintenance Practices .....	
Option 1E: Light-Duty Diesel Vehicles.....	
2. Fuel Displacement Options	
Option 2A: Fuel Cells .....	
Option 2B: Electric Battery Technologies .....	
Option 2C: Grid-Connected Hybrids .....	
Option 2D: CNG for Light Duty Vehicles.....	
Option 2E: Liquefied Petroleum Gas (LPG) .....	
Option 2F: Alcohol Fuels in Flexible Fuel Vehicles .....	
Option 2G: Use of Ethanol as a Gasoline Blend.....	
Option 2H: LNG and Advanced NG Engines for Medium- and Heavy-Duty Vehicles .....	
Option 2I: Fischer-Tropsch Diesel .....	
Option 2J: Biodiesel.....	
3. Pricing Options	
Option 3A: Gasoline Tax .....	
Option 3B: Pay-at-the-Pump Auto Insurance .....	
Option 3C: Tax on Vehicle Miles Traveled.....	
Option 3D: Feebates .....	
Option 3E: Registration Fee Transfer .....	
Option 3F: Purchase Incentives for Efficient Vehicles.....	
4. Other Options	
Option 4A: Expanded Use of Public Transit .....	
Option 4B: Land Use Planning .....	
Option 4C: Telecommuting .....	
Option 4D: Reducing Speed Limits.....	
Option 4E: Voluntary Accelerated Vehicle Retirement .....	
Appendix A: Consumer Surplus .....	
Appendix B: Ethanol Demand and Supply Analysis.....	

## INTRODUCTION

Assembly Bill 2076 (Chapter 936, Statutes of 2000) requires the California Energy Commission and the California Air Resources Board to develop and submit a strategy to the Legislature to reduce petroleum dependence in California. The statute requires the strategy to include goals for reducing the rate of growth in the demand for petroleum fuels. Options to be considered include increasing transportation energy efficiency and using non-petroleum fuels and advanced transportation technologies including alternative fueled vehicles and hybrid vehicles.

The Energy Commission and the Air Resources Board have developed a program and methodologies to evaluate and analyze these possible options. The goal of this effort is to provide policy makers with a robust analysis of the possible measures that could be implemented to meet the fuel demands of consumers and industry. This analysis needs to account for the costs of these measures as well as the benefits. The overall effort is guided by consultant services provided by Acurex Environmental, an Arthur D. Little Company.

This work has been divided into several tasks and assigned to the appropriate agency staff.

- The Air Resources Board leads the first task to determine the possible benefits of reducing the demand for gasoline and diesel fuel in California.
- The second task is led by the Energy Commission to determine the future demand for refined products, especially gasoline and diesel fuels. The results of this task are contained in a report entitled *Base Case Forecast of California Transportation Energy Demand* that was published December 2001. In this report, the Energy Commission projected total personal income, population, vehicle miles traveled, and demand for gasoline and diesel fuels. The report also presents forecasted prices for petroleum and refined products through 2020 (with an extrapolation through 2030).
- The Energy Commission also leads the third task, which is the focus of this staff report. The objective of this task is to assess possible options to reduce petroleum dependency and to determine the level of petroleum reduction and costs.
- The Energy Commission and the Air Resources Board will jointly lead Task 4, which provides integration of the results of Tasks 1, 2, and 3. Staff will develop strategies and provide recommendations to stakeholders for discussion. Alternative strategies may also be developed and presented to the Energy Commission and Air Resources Board. Recommendations for establishing statewide petroleum reduction goals and possible policies to achieve these goals will be considered for adoption and presented to the Governor and Legislature.

### Options to Reduce California's Petroleum Dependence

The potential for reducing California's petroleum dependence can be assessed by reviewing a wide range of technology, fuel and demand reduction options. This report describes the

methodology used in the current analysis and presents a detailed evaluation of each option. The options that were evaluated are discussed below and divided into four categories.

- **Group 1: Fuel Efficiency Options.** Staff evaluated a variety of measures to improve transportation energy efficiency. These measures include improved vehicle fuel economy, use of fuel-efficient tires, fuel-efficient vehicles in government fleets, improved vehicle maintenance, and others.
- **Group 2: Fuel Displacement Options.** The introduction of advanced technologies, such as hybrid electric and fuel cell vehicles, can be effective in reducing petroleum dependence. In addition, the introduction of non-petroleum and alternative fuels can displace both gasoline and diesel fuel.
- **Group 3: Pricing Options.** Pricing measures tied either to fuel use or vehicle miles traveled can be effective in curtailing consumer fuel demand. Direct incentives, such as rebates, tax credits, or purchase incentives were also examined.
- **Group 4: Other Options.** Staff explored other policies to reduce the demand for gasoline and diesel fuel including telecommuting, land use planning, and reducing speed limits.

All of the options evaluated are briefly described in sections of this report and structured in the following manner:

- **Description:** A short description of the option being evaluated.
- **Background:** A general discussion of the technology involved, any related legislation or other material needed to understand the issues involved with that particular option.
- **Assumptions and Methodology:** A discussion of the general assumptions and methodology that were used in developing the analysis.
- **Status:** For those options in Group 2 only, a discussion is included that describes the current state of development for that particular technology.
- **Results:** The specific quantified results from the analysis showing the option's petroleum reduction compared to the base case.
- **Key Drivers and Uncertainties:** A listing of those key drivers and uncertainties that could significantly change the results.

## Methodology for Evaluating Petroleum Reduction Options

The staff 's methodology is based on a step-by-step approach, using the following five steps:

1. Collect data or information about each option.
2. Identify and apply an appropriate method or tool to analyze each option.
3. Calculate the petroleum reduction compared to the base case.
4. Determine the costs and benefits associated with the option.
5. Evaluate and compare the various options using common metrics.

Although the methodology for Group 2 used the same general approach, the actual comparison method differed. A detailed description of this variation is discussed later in this chapter.

### Step 1. Collect Data or Information

Appropriate data or information was needed to characterize the measure and provide input for the analysis. An important part of this step was identifying timing of the measure, expected market penetration rates and cost of implementation. In some cases staff used consultant information and in other cases staff developed independent estimates. Staff either collected new data related to costs and estimated fuel savings or updated data from previous analyses.

### Step 2. Identify and Apply an Appropriate Method or Tool

Staff used one of two approaches to conduct the analysis of each option. The CALCARS model, which provided the gasoline base case forecast for light duty vehicles, was used for analysis of broad measures affecting pricing or fleet fuel economy. For other measures staff developed scenarios to directly estimate the petroleum savings, program and vehicle costs, and value of fuel savings.

**CALCARS Model.** The CALCARS model forecasts future travel and energy demand for California's fleet of light duty vehicles. Based on vehicle attributes (e.g., fuel cost per mile), the model predicts vehicle ownership and use. The model can forecast the fuel demand under a proposed option and explicitly quantify the change from the base case in California travel and fuel use resulting from the option's implementation. An option's petroleum reduction is determined by subtracting its demand outcome from the forecast for the base case.

**Scenarios.** For options not within the analytic framework of the CALCARS model, the evaluation method used was based on a scenario approach. Staff developed a common strategy needed to increase market penetration for a variety of fuel displacement options, which assumed:

- Advancement in technology performance under mature market conditions.
- Reductions in costs due to technology advancement or commercial production levels.
- Resolution of market barriers, such as providing adequate and convenient fueling infrastructure.

- Differences in costs and impacts for mature technologies, when compared to technologies that require long-term research and development to reach commercial deployment.
- Other plausible market conditions or outcomes.

### **Step 3. Determine the Petroleum Reduction Compared to Base Case**

The staff determined the petroleum reduction due to the option based on the assumed efficiency improvement, reduction in vehicle miles traveled, or the level of fuel substitution when compared to the base case forecast. The total cost of implementing the option for the consumer and program costs for the state were then compared to the value of the fuel savings to determine the direct net benefit of the option (see discussion in Step 4 below).

### **Step 4. Determine the Costs and Benefits**

Where possible, staff determined the present value of direct net benefits of the options for three time periods: 2002-2010, 2002-2020 and 2002-2030 using an annual discount rate of 5 percent. The 5 percent rate reflects the discount rate applicable to the value of savings over time for the long-term perspective of society or government. For Group 2 (Fuel Displacement Options), present value direct net benefits were determined over the expected vehicle life but not for a specific time period.

As stated above, the benefits and costs do not include the externality costs as part of this report. These costs will be added later. For some options, such as enhanced land use planning, the direct net benefit could not be determined due to the variety of non-energy costs associated with the option and the unknown value of changes in utility for the traveler due to land use policies.

Where possible, results have been expressed in terms of Non-Environmental Net Direct Benefits which consists of the sum of Net Consumer Benefits and Impact on Government Revenues as described below.

**Net Consumer Benefits.** An important economic metric to gauge and compare the societal value of different actions that affect the market place is the resultant change in net consumer benefits (also known as consumer surplus). In simple terms, the difference between a consumer's maximum willingness-to-pay and the market price of a good is described as net consumer benefits. When an increase in net consumer benefits occurs, the benefits per unit cost received by consumers increases, as well. From a societal perspective, an action that affects the market for goods and services by increasing net consumer benefits is preferred.

- *Net Consumer Benefits and CALCARS.* The CALCARS model operates under a basic economic concept that consumers will maximize their utility (self-interest or receipt of benefits provided by a product or service) when choosing goods and services, subject to market prices and their ability or willingness to pay those prices. In general, however, sellers of goods and services cannot isolate each consumer and charge the maximum he or she would be willing to pay. Thus, the seller will establish a price that is usually less than this maximum. Such market behavior favors the consumer because they will generally pay a price that is less than what they were prepared to pay. Thus, from the consumer's viewpoint,

they received some benefits that they valued but did not have to pay for; the money that would have been spent due to a higher price can now be used to acquire other benefits. The value of this additional benefit can be called a surplus, and it is an inherent part of the total benefits received by a consumer.

The net present value of net consumer benefits and any subsidy or revenues associated with the measure can be derived from the numerical results predicted by CALCARS. The net consumer benefits value includes specific vehicle attributes addressed by the model, including fuel cost per mile and vehicle cost to enable the value of fuel savings and other changes in utility to the consumer to be measured. The total direct net benefits for an option are the net consumer benefits plus associated tax revenues minus state subsidies, if any, for the option. While vehicle class size is included, vehicle weight change that may be important for fuel economy measures is not addressed in the model analysis. The CALCARS model can generally be used to evaluate the cost-benefit of pricing options and vehicle fuel economy options.

- *Net Consumer Benefits and Scenarios.* Due to the absence of information on changes in utility that consumers might experience, the analytic rigor of CALCARS could not be duplicated for those options where scenarios are employed as the evaluation approach.

To achieve the petroleum reductions estimated for each scenario, staff assumed an expenditure that is made to change the unit price for a certain product, or to increase the sale of a certain product. For example, this expenditure could be a direct incentive to reduce the purchase price, or the reduction in taxes that might normally be levied. The minimum change in net consumer benefits for such a scenario would be equal to the present value of one-half of the cost related to the option (i.e., units sold times the change in price).

In the case of a scenario where consumers are provided information that increases the sale of a certain product without changing its price, the change in net consumer benefits is approximately equal to the additional value placed on the product. For example, if a consumer believes that buying a set of low rolling resistance tires will produce a benefit in reduced fuel consumption cost, the change in net consumer benefits is at least equal to the present value of the perceived benefit over the life of the tires.

**Impact on Government Revenues.** The impact on government revenues is the sum of any increases in consumer costs that are borne by government and any change in excise tax collection. Moving beyond limited, niche market levels requires direct cost reductions (savings) for consumers. Staff therefore assumed that any net consumer costs (negative “benefits”) transfer to government in one way or another, although the mechanism is not identified.

## **Step 5. Use Common Metrics for Comparison**

Staff used a cost-benefit framework to measure, evaluate and compare the value of different petroleum reduction options, using validated and uniform inputs whenever possible. Each option was compared using both the direct and indirect benefits, including:

1. Consumer net benefits (includes value of fuel savings) except for Group 2 as explained below.
2. The impact on government revenues (taxes, program costs).

Using these values and the analysis performed in Steps 1 through 4 above, staff then determined the direct net benefits (the difference between the costs and benefits) to society (not including the environmental benefits, to be added later).

Using these steps and the common metrics described above, staff then determined two key outputs, expressed as the net present value of:

1. The consumer costs or savings per vehicle expressed in dollars per vehicle.
2. The net costs or savings per gallon of gasoline or diesel displaced, expressed in dollars per gallon.

Taken together, these two outputs are combined to show the annual fuel costs or savings per vehicle per year.

## **Group 2 Variation**

Those options included in Group 2 (Fuel Displacement) required a slightly varied approach from the above methodology due to the inherent differences in their market status. Because each technology in that group is at a different point of development, both the timing and the likelihood of meeting development program goals for cost and performance varies for each option.

In order to compare them, staff evaluated each option at some point in time when it has reached both an “intermediate market” and a “mature market” condition. Where possible, staff assessed the level of research and development funding needed to make the technology mature. Staff also provided an estimate of the status of development where possible. In addition, staff assumed that if a technology reaches a mature market condition, it would do so no later than the year 2030.

**Intermediate Market.** Where possible, a discussion is included on the factors leading to an intermediate market, where some vehicle sales occur, possibly stimulated more by government mandate than market economics. Certainly all technologies need to have an intermediate market before they can transition to a mature market, but each option’s technology is different, and at a different point of its development.

**Mature Market.** Staff assumed that in a mature market, technology development targets are met and that the technology has attractive life cycle costs, at least for some market conditions. Staff calculated present value life cycle costs of owning the technology over its expected practical lifetime. For some options, the life-cycle costs of the vehicle were evaluated over the 2008 to 2018 time period, while other technologies that mature later were evaluated over the 2015 to 2025 time period. Staff assumed a discount rate of 12 percent (real, without inflation) to bring fueling costs to present value. Results reported are for each gallon of gasoline or diesel (as applicable) displaced, not per gallon of alternative fuel used. This approach gives an approximation of present value, life-cycle value of the development targets in terms of cost

effectiveness of the targets relative to the gasoline or diesel fuel technologies they would displace.

Results are expressed in terms of the net present value of the cost (expressed as a positive value) or savings (expressed as a negative value) to operate the technology over its lifetime, in constant, year 2002 dollars per vehicle, per gallon of gasoline or diesel displaced. This assessment is from the perspective of the owner of the option's technology, and from the government, including the impact of any lost fuel excise taxes. Staff also provided the net cost, which is based upon both consumer and government costs. In some cases, there is a savings to the consumer but a cost to the government (in the form of lost taxes). In other cases, there is a cost to the consumer. For these cases, staff assumed that government will cover these costs, in addition to losing excise tax dollars.

The cost to develop the technology is excluded from the analysis. This is because staff expects incremental vehicle costs to include any private monies spent on R&D. Also, information on the cost of developing each option's technology is generally not publicly available. In addition, private R&D funding varies significantly among different automotive companies and fuel providers.

**Gasoline and Diesel Fuel Displacement.** For Group 2, staff estimated the amount of gasoline or diesel (as appropriate) displaced in two target years, either 2010 and 2020 or 2020 and 2030. Staff assumed that most of the options will be sufficiently mature to reach 4 percent fuel displacement by 2010 and 10 percent fuel displacement by 2020 (percentages of fleet population). This non-linear ramp-up to a 10 percent market penetration was selected as a reasonable upper bound based upon historical efforts to introduce alternative fuel technologies. For those option technologies that need a longer period of time to reach the mature market condition, staff assumed they reach 4 percent market penetration by 2020 and 10 percent by 2030.

If more than one option reaches a mature market condition, the amount of gasoline or diesel displaced will be less than the sum of the two assuming they displace the same conventional fuel. This effect occurs because the options would each "take" a portion of each other's market, in essence, competing against each other rather than the conventional gasoline or diesel fuel. Where possible, a discussion of factors that may influence the pace of this market maturing process is included.

**Station Module Spreadsheets.** Staff used a Station Module spreadsheet to estimate fuel costs for non-petroleum Group 2 options (and Option 1E). For these, staff obtained wholesale cost data using available references such as CEC data or U. S. Energy Information Administration information for wholesale fuel prices such as "sale to re-sellers" prices; added an increment to "bid" the fuel away from other re-sellers, if needed; then added annualized capital costs and a retailer's mark-up of 15 cents per physical gallon. Staff also included existing excise and sales taxes to obtain a retail price. Staff determined annualized capital costs by estimating the total capital cost to upgrade an existing refueling facility to store and dispense the non-petroleum fuel, considering the number of vehicles that could be served by the size of the incremental addition. For some options, several dispensers are associated with the non-petroleum fuel addition while

for others costs were estimated per dispenser. This can be seen by examining the number of vehicles on the refueling station spreadsheet. Either approach is acceptable because results are reported per vehicle. Staff assumed private refueling facility ownership and used a 12 percent return on capital investment over a 20 year investment period. Specific assumptions can be determined by reading the Station Module spreadsheets. Some Group 2 options use conventional gasoline or diesel fuel and conventional refueling stations are assumed with no increase in refueling infrastructure costs. For these, there are no Station Module spreadsheets.

**GROUP 1**  
**FUEL EFFICIENCY OPTIONS**

## **Option 1A**

### **Improved Vehicle Fuel Economy**

**(Analysis by Nalu Kaahaaina, Chris Kavalec and Michael Jackson)**

#### **Description**

This option is based on increasing light-duty vehicle efficiency by means of advanced vehicle technology. The technologies covered include advanced internal combustion engines, hybrid-electric propulsion, 42V electrical systems, integrated starter-generators as well as a myriad of other devices that enhance fuel economy relative to more traditional vehicle equipment. Increasing fuel economy levels provides the opportunity to meet transportation demand with less fuel. As a result, increasing vehicle efficiency, particularly in mass-production vehicles that constitute the majority of transportation energy demand, can result in significant petroleum reductions.

#### **Background**

Fuel economy improvements for commercially viable, production-volume vehicles is a topic that has produced significant attention and study. Due to the significant capital investments in vehicle manufacturing, as well as the product cycles of automobiles, most work examining changes in automotive product offerings consider scenarios several years in the future. Vehicle fuel economy analyses performed by the National Research Council<sup>1</sup> (NRC), the American Council for an Energy-Efficient Economy<sup>2</sup> (ACEEE), and Energy and Environmental Analysis, Inc.<sup>3</sup> (EEA) were used to estimate future fuel economy improvements. These works were consulted as they collectively provide a range of potential costs, fuel economy levels, and market penetrations. The findings of these studies are used to estimate the petroleum reductions that are possible for California.

The NRC, ACEEE, and EEA studies together consider several technology levels or “packages.” These packages include various technologies, and are not limited to a particular device or implement. Rather, these technology options are assembled into systems that would collectively deliver improved fuel economy. Table 1A-1 summarizes the technology packages examined that are based on these studies.

#### **Methodologies**

Two separate methodologies were employed in this analysis to estimate the impact of fuel economy technologies and their associated costs. The FUTURES spreadsheet model was used to simulate California fleet fuel savings and the present worth of consumer out-of-pocket costs or savings for five different technology packages. A sixth technology package was simulated using the California Energy Commission (CEC) CALCARS model. CALCARS is a vehicle choice model that considers consumer preference for vehicle attributes such as vehicle price, performance, and fuel economy. As such, it allows a more comprehensive analysis of the impacts of higher fuel economy. For example, CALCARS can estimate the welfare effects to vehicle owners of degradation in vehicle performance that may occur with a measure designed to

**Table 1A-1. Description of Technology Options**

<b>Technology Package</b>	<b>Description</b>
NRC Path 3	Mass reduction, streamlining, lower rolling resistance tires, variable valve timing, engine supercharging/downsizing, 42V, improved transmission. Significant advances in emission control technology necessary to meet regulatory requirements.
ACEEE Moderate	Mass reduction, streamlining, lower rolling resistance tires, high-efficiency engines (50kW/L), integrated starter generator, 42V, CVTs (Cars), 5-speed automatics (light trucks).
ACEEE Advanced	Moderate + additional mass decreases + direct-injection gasoline engine (55kW/L), and efficiency-optimized transmission shifting.
ACEEE Mild Hybrid	Electric drive propulsion rated at 15% of peak power (15%-18% FE improvement over Advanced Package).
ACEEE Full Hybrid	Electric drive propulsion rated at 40% of peak power (29%-33% FE improvement over Advanced Package).
EEA	Mass reduction, streamlining, lower rolling resistance, cylinder deactivation, supercharging, variable valve timing, advanced transmissions, mild hybrids, full hybrids.

increase vehicle fuel economy.<sup>4</sup> However, this means that CALCARS requires the projection of a variety of vehicle attributes for a given scenario, and such projections were not available in the NRC and ACEEE analyses. Therefore, the FUTURES model was used to simulate the impacts of fuel economy technology packages based on these two studies. The EEA technology package (designed to provide the appropriate vehicle attribute projections) served as the basis for the CALCARS simulation. The FUTURES simulations extend out through the year 2050 while the CALCARS simulation runs through 2030. The results of both models are meant to provide an assessment of what is possible in California.

Technology and cost inputs for both models are based on studies that assume light-duty vehicle fuel economy technologies being implemented at the national level. As a result, the costs listed in these reports are based on amortizing capital investments across national vehicle sales. If these same technologies were developed for smaller production volumes, consistent with California's annual sales, the resulting incremental costs to California consumers would be higher than those listed in these studies.

**FUTURES Model.** Arthur D. Little, Inc developed a spreadsheet tool to estimate long-term fuel use characteristics of California's light-duty vehicles. The calculations of incremental cost, fuel consumption and savings, as well as vehicle population dynamics, were integrated into this model. In addition to fuel use, FUTURES tracks direct costs and fuel savings benefits to vehicle consumers, but does not account for consumer value of other vehicle attributes such as performance.

**CALCARS Model.** CALCARS is a vehicle choice model that the CEC uses to forecast future energy demand in the light-duty vehicle sector in California. It is a multinomial logit model that

accounts for consumer preference in terms of vehicle attributes, including vehicle price, fuel economy, range, performance and the number of vehicle makes and models available per class. CALCARS applies these consumer preferences to calculate vehicle sales and population by size class, annual vehicle miles traveled, and fuel consumption for California's light-duty fleet. This model was used in the Base Case forecast of gasoline demand in California.

## **Assumptions**

Table 1A-2 shows the level of fuel economy improvement modeled for the various cases considered. CALCARS breaks down the California light-duty fleet (including passenger cars, light-duty trucks, vans, and sport utility vehicles with a Gross Vehicle Weight Rating of 10,000 pounds or less) into 13 vehicle classes. For consistency, these 13 classes were used in the FUTURES simulations. The numbers in each class for 2000, the base year used in CALCARS, come from California Department of Motor Vehicles registration data. The baseline fuel economy values in this table are predicted by EEA for 2002.

For the FUTURES simulations, fuel efficiency improvements relative to the Base Case forecast were determined by factoring up the EEA baseline estimates using the percent improvements determined in the NRC and ACEEE studies. Due to the complexity of designing and manufacturing automobiles, it was assumed for these five scenarios that six years would be needed before new technology could enter the California market place. In these simulations, all vehicle classes were assumed to reach the levels given in Table 1A-2 immediately afterward (in model year 2008). For the bounding cases, improved vehicle technology is assumed to comprise 100 percent of new vehicle sales beginning in MY2008. The assumption that new fuel economy technology could have 100 percent market penetration right away is certainly unrealistic. This simplification, however, is applied equally to each of the bounding scenarios, enabling each to be compared side-by-side. This report is not meant to suggest that these market penetrations are in any way likely; rather they assist in constructing an upper bound for what is possible in terms of petroleum reduction and fuel savings.

For the CALCARS simulation, fuel economy improvements, vehicle cost increases, and changes in other attributes relative to the Base Case were projected directly by EEA. In this case, fuel economy for new vehicles increased gradually (beginning in 2008) over a twelve-year period to match the production cycle followed by manufacturers. The entries in Table 1A-2 for EEA are projections for the model year 2008. By 2020, projected fuel efficiencies were 15 to 35 percent higher, depending on vehicle class, than the figures for 2008.

Table 1A-3 lists the light-duty vehicle classes, current vehicle populations, as well as the projected new vehicle sales in 2002 as predicted by CALCARS. CALCARS determines new vehicle fuel use and sales distributions in each modeling year. However, the change in vehicle distribution is relatively small and was held constant at the 2002 level shown in Table 1A-3 for the FUTURES simulations.

In addition to state-specific parameters describing existing and future light-duty vehicles, estimates for vehicle retirement rates were required for the FUTURES simulations. These estimates were pulled from the California Air Resources Board (ARB) EMFAC model to project vehicle usage and retirement trends over time.<sup>5</sup> Accounting for lifecycle events, from new

vehicle sales, use over the age of the vehicle, and vehicle retirement, enables long-term, fleet-wide trends to be captured. This step was not required in the case of CALCARS, where vehicle retirement is endogenous to the model.

**Table 1A-2. Fuel Economy Levels for Each Scenario**

Vehicle Class	On-Road Fuel Economy (mpg)						
	Baseline	Moderate	Advanced	Mild Hybrid	Full Hybrid	NRC Path 3	Duleep MY '08
Mini Car	38.4	54.6	60.3	70.3	79.2	53.9	42.4
Subcompact	29.1	41.4	45.7	53.3	60.0	40.8	33.7
Compact	25.6	36.4	40.2	46.8	52.7	36.5	28.7
Midsize	22.0	34.3	38.4	44.2	49.7	33.5	25.2
Large Car	20.2	31.5	35.4	40.6	45.7	31.9	23.3
Sports Car	22.7	35.3	39.7	45.5	51.2	35.8	25.1
Mini Van	22.1	29.8	35.6	41.8	47.1	35.1	24.2
Standard Van	15.1	21.9	26.1	30.7	34.6	24.1	16.8
Compact Truck	19.2	30.2	35.5	41.1	46.4	30.4	21.3
Standard Truck	14.1	20.7	24.4	28.2	31.8	22.5	17.9
Mini SUV	23.0	35.0	40.9	48.1	54.1	34.8	19.0
Compact SUV	16.8	25.5	29.9	35.1	39.5	27.3	16.9
Standard SUV	13.8	21.0	24.6	28.8	32.4	22.8	26.4
On-Road Avg. FE	20.8	30.5	34.9	40.6	45.7	31.8	27.1
EPA Rated	24.7	36.3	41.6	48.3	54.4	37.9	32.2

**Table 1A-3. Existing Light-Duty Vehicles and Projected New Vehicle Sales for 2002**

Class	Total 2002 Light-Duty Fleet		New 2002 Vehicle Sales	
	Vehicle	Fraction (%)	Vehicles	Fraction (%)
Mini Car	914,962	4.0	31,551	1.7
Subcompact	3,183,977	13.9	287,530	15.9
Compact	3,765,598	16.4	282,328	15.6
Midsize	3,441,453	15.0	268,228	14.8
Fullsize	1,046,000	4.6	74,446	4.1
Sports Car	1,650,610	7.2	81,892	4.5
Compact Truck	1,956,364	8.5	99,114	5.5
Standard Truck	2,282,808	9.9	184,452	10.2
Mini Van	1,551,758	6.8	143,951	8.0
Standard Van	524,149	2.3	27,683	1.5
Mini SUV	96,661	0.4	12,859	0.7
Compact SUV	1,901,749	8.3	243,426	13.5
Standard SUV	672,881	2.9	71,670	4.0
Total	22,988,969	100.0	1,809,130	100.0

**Vehicle Population Dynamics in the FUTURES Simulations.** Given the degree of complexity necessary to identify and track long-term vehicle trends noted above, some simplifying assumptions have been made for the FUTURES model. While these simplifications are not strictly accurate, they are consistent with the uncertainties implicit in any long-term forecast. Each FUTURES simulation assumes identical vehicle population characteristics (sales, usage, and retirement). The assumptions and techniques used to model long-term light-duty fleet trends are discussed below.

- *New Vehicle Sales.* Vehicles are assumed to enter the fleet each model year (MY), with total vehicle sales increasing over time. While new vehicle sales increase over the forecast time

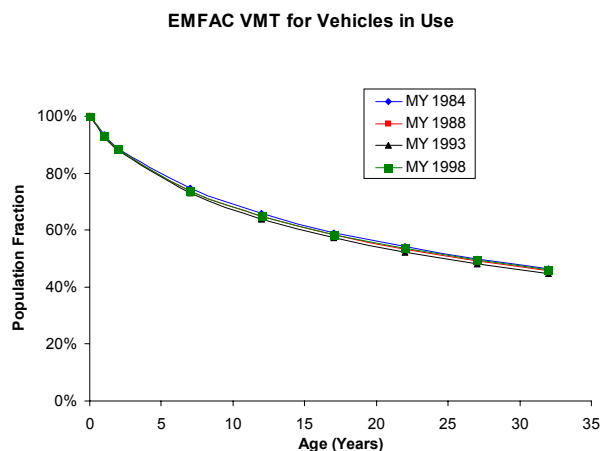
period, the distribution of these sales across the 13 light-duty vehicle classes is held constant over time. The sales distributions used in this work are based on CALCARS estimates for MY2002, and held constant over the span of this analysis. As an example, new California vehicle sales for MY2010 are estimated to be approximately 2.1 million vehicles, with 14.8 percent or 312,000 vehicles sold in the midsize class. For MY2020, total light-duty vehicle sales are estimated at 2.5 million units with 14.8 percent of all sales (371,000 cars) coming from the midsize class. Table 1A-4 summarizes new light-duty vehicle sales over the span of this analysis, and the distribution of these sales, by class.

- *Vehicle Use.* Driving use for a particular vehicle tends to decrease as the vehicle ages, with transportation demand tracked by total vehicle miles traveled (VMT). VMT over any vehicle population is simply the sum of total mileage accumulated by that population over a given timeframe. This analysis examines VMT for each model year of vehicle sales and tracks it as a given model year ages. For the purposes of this analysis, each model year is assumed to age identically, in terms of VMT decline over time. Figure 1A-1 shows the assumed change in VMT and vehicle population over time.

**Table 1A-4. Projected New Vehicle Sales for Future Model Years**

Class	Projected New Vehicle Sales				
	MY 2010	MY 2020	MY 2030	MY 2040	MY 2050
Mini Car	35,087	41,737	48,223	57,078	67,558
Subcompact	324,953	386,546	446,618	528,622	625,684
Compact	326,583	388,485	448,859	531,275	628,823
Midsize	311,992	371,128	428,804	507,538	600,728
Fullsize	84,389	100,385	115,986	137,282	162,489
Sports Car	89,657	106,652	123,226	145,852	172,632
Compact Truck	115,393	137,265	158,597	187,718	222,185
Standard Truck	213,752	254,268	293,783	347,725	411,572
Mini Van	170,912	203,308	234,903	278,034	329,084
Standard Van	32,284	38,403	44,371	52,518	62,161
Mini SUV	17,704	21,060	24,332	28,800	34,088
Compact SUV	303,916	361,522	417,704	494,400	585,178
Standard SUV	80,932	96,272	111,233	131,657	155,831
Total	2,107,554	2,507,031	2,896,636	3,428,499	4,058,103

**Figure 1A-1. Vehicle Miles Traveled Over a Model Year's Lifetime**



**Advanced Technology Vehicles.** In the FUTURES simulations, new light-duty vehicles sold in 2008 and beyond are assumed to be composed entirely of one type of technology. The ACEEE Moderate and Advanced Scenarios, as well as the NRC case, include only conventional gasoline vehicles, while the Mild and Full Hybrid scenarios include these technologies only.

In the CALCARS simulation, conventional as well as mild and full hybrid vehicles are assumed to be available. Table 1A-5 shows the vehicle technologies included in the simulation by size class. Projected availabilities come from analysis by EEA.

**Table 1A.5: Availability of Vehicles by Class for CALCARS Simulation**

Vehicle Class	Conv. Gasoline	Mild Hybrid	Full Hybrid
Mini Car	√	√	√
Subcompact	√	√	√
Compact	√	√	√
Midsize	√	√	
Large Car	√	√	
Sports Car	√		
Compact Pickup	√	√	
Standard Pickup	√	√	
Minivan	√	√	√
Standard Van	√		
Mini SUV	√	√	√
Compact SUV	√	√	√
Standard SUV	√	√	

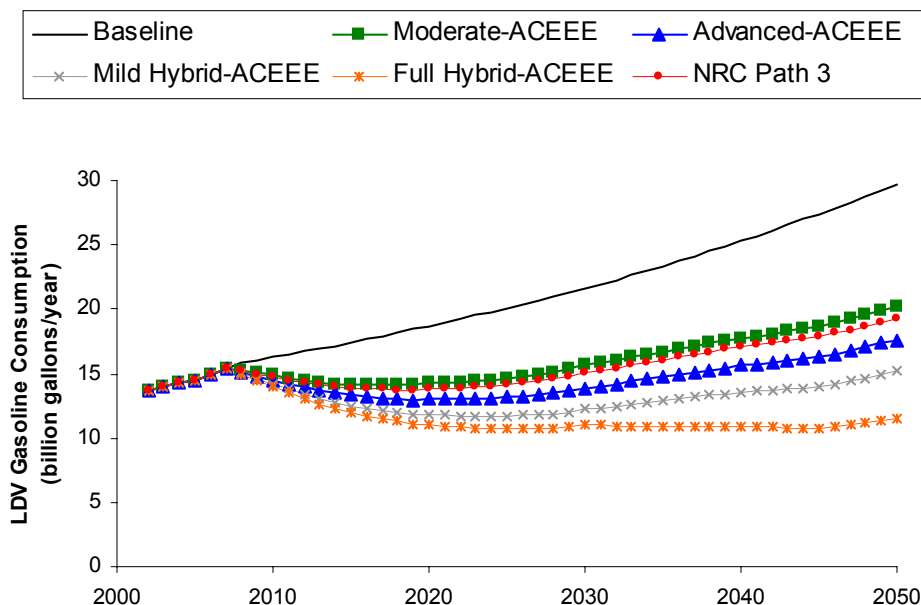
## Results

**Results from the FUTURES Simulations.** Gasoline demand reductions for each scenario run with the FUTURES model (corresponding to the new vehicle fuel economy levels listed in Table 1A-2) are given in Table 1A-6. Potential fuel savings are bounded by the ACEEE Moderate Package on the lower end, with the upper bound corresponding to ACEEE-Full Hybrid technology. Figure 1A-2 shows projected fuel consumption for each scenario. Annual reductions in gasoline demand relative to the Base Case increase over time as more and more of the total LDV fleet in California is affected. These reductions may be somewhat overstated, since the simulations do not account for the “rebound” effect of VMT due to lower fuel costs per mile.

**Table 1A-6. Gasoline Demand Reductions from FUTURES Simulations (million gallons)**

Case	Annual Gasoline Reduction				
	2010	2020	2030	2040	2050
Moderate	1,421	4,437	5,940	7,525	9,472
Advanced	1,777	5,662	7,687	9,671	12,040
Mild Hybrid	2,118	6,834	9,362	11,729	14,503
Full Hybrid	2,352	7,642	10,516	14,401	18,229
NRC Path 3	1,539	4,843	6,517	8,223	10,319

**Figure 1A-2. Fuel Consumption for Each FUTURES Scenario from 2002 to 2050**



The increased fuel savings associated with higher fuel economy levels come with higher vehicle costs due to the installed technologies. Table 1A-7 shows the net direct (non-environmental) benefit results for 2010, 2020, 2030, 2040, and 2050. These calculations are net amounts relative to the Base Case forecast. The numbers are a net of higher vehicle costs, reduced expenditures on fuel, and the loss in government excise tax revenue.<sup>6</sup> These cost/benefit figures show that ACEEE-Moderate and ACEEE-Advanced scenarios provide the largest net present values, as they predict improved fuel economy at comparatively lower costs than the other options. The figures may be somewhat understated in the early years since the FUTURES simulations assume that increments to vehicle prices (relative to Base Case levels) are paid in full when the vehicle is purchased, when in reality buyers typically pay for a new auto over a period of years.

The cost efficiency of these costs/benefits can be considered in the payback period for each scenario. The ACEEE-Moderate and ACEEE-Advanced scenarios have the shortest payback periods (approximately 5 years) whereas the ACEEE-Mild Hybrid and NAS Path 3 scenarios have payback periods of 22 and 32 years, respectively. The ACEEE-Full Hybrid scenario does not pay for itself within the 2050 time horizon of this study.

**Table 1A-7. Net Direct Benefits\* for FUTURES Simulations**

Present Value Direct Net Benefits (5% discount rate, million 2001\$)					
Case	2002-2010	2002-2020	2002-2030	2002-2040	2002-2050
Moderate	-2,676	4,351	16,192	25,743	33,773
Advanced	-4,180	2,577	16,443	27,897	37,386
Mild Hybrid	-12,431	-24,401	-21,804	-18,045	-14,074

Full Hybrid	-18,816	-45,579	-52,098	-52,962	-50,809
NAS Path 3	-9,907	-21,225	-21,779	-21,019	-19,353

\* Includes the net of the increase in vehicle costs and the savings in fuel expenditures, minus the loss in excise tax revenues. Does not include environmental benefits.

**Results from the CALCARS Simulation.** Table 1A-8 shows the projected reductions in gasoline demand from the CALCARS simulation for the years 2010, 2020, and 2030 in California, in both absolute and percentage terms. Average fuel efficiency for new cars reaches 34.8 mpg by 2010 and 41.4 mpg (EPA rated) by 2020, compared to 29.8 mpg and 30.1 mpg, respectively, in the base case. For light trucks, the corresponding numbers are 24.2 mpg and 28.0 mpg (compared to 20.4 mpg and 20.7 mpg). Annual reductions in gasoline demand relative to the Base Case increase over time as more and more of the total LDV fleet in California is affected.

**Table 1A-8. Gasoline Demand Reductions from CALCARS Simulation**

	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	543	2,792	4,196
Reduction From Base Case Demand (percent)	3.2	14.3	18.7

\*Gasoline displacement relative to base case.

Table 1A-9 shows the net-benefit results for consumers and the impact on government revenues for 2010, 2020, and 2030. These calculations are net amounts relative to the Base Case forecast.

Net consumer benefits (the change in consumer surplus) include both “monetary” and “non-monetary” impacts. The monetary impacts are the net of the effects of the increase in vehicle costs and the private benefits of reduced fuel consumption. The non-monetary category includes the impact of higher fuel economy on vehicle performance. For most years, increased fuel efficiency comes at the expense of vehicle performance (acceleration and top speed) relative to the Base Case values. In later years, however, the fuel economy technologies installed actually improve vehicle performance (e.g., variable valve timing).

The total change in consumer surplus is positive; the benefits of reduced fuel consumption outweigh the cumulative effects of higher average vehicle prices and the degradation (in most years) in vehicle performance. One criticism of measures designed to improve fuel efficiency has been that consumers are more interested in higher vehicle performance than they are in fuel efficiency gains; these results show that consumers are better off with improved fuel economy even when performance effects are considered.<sup>7</sup>

The negative entries for government revenues represent the reduction in gasoline excise taxes (less gasoline sold) collected relative to the Base Case forecast. Net direct benefits (non-environmental) are calculated by summing net consumer benefits and the impact on government revenues.

**Table 1A-9. Present Value (2002 Benchmark, 5% Discount Rate) of Direct Net Benefits Relative to Base Case Forecast for CALCARS Simulation (million 2001\$)**

	Net Consumer Benefits (Change in Consumer Surplus) (A)		Government Revenues (B)	Non- Environmental Direct Benefits (A+B)
Time Period	Monetary*	Non-Monetary**		
2002-2010	697	-73	-274	350
2002-2020	11,870	-52	-3,420	8,398
2002-2030	29,383	1,515	-7,607	23,291

\* The net of the increase in average vehicle cost and the private benefits of reduced fuel consumption.

\*\* Includes the impact of higher fuel economy on vehicle performance.

### Key Drivers and Uncertainties

Several variables impact the results for each scenario. Changes in these variables, such as technology cost or fuel price, can dramatically alter the outcomes of these findings. A brief discussion of the most influential factors in this analysis is provided here to inform the reader of the sensitivities of this effort. In addition to these sensitivities, there are several nuances in the analysis – such as fuel economy and fuel consumption -- that are highlighted here to draw key issues to the fore.

**Gasoline Fuel Price.** Consistent with the CEC’s projections of fuel prices for this study, FUTURES cases assumed a constant fuel price of \$1.64 per gallon for gasoline from 2008 to 2050. Sensitivity analyses were performed for the FUTURES simulations on gasoline prices with a low price of \$1.47 per gallon and a high price of \$1.81 per gallon, representing a cost range of one standard deviation. The corresponding net present values for these “sensitivity runs” are listed in Tables 1A-10 and 1A-11, for each scenario.

**Table 1A-10. Net Direct Benefits\* for \$1.47/Gallon Gasoline Price**

Present Value Direct Net Benefits (5% discount rate, million 2001\$)					
Case	2002-2010	2002-2020	2002-2030	2002-2040	2002-2050
Moderate	-3,025	1,163	10,066	17,365	23,615
Advanced	-4,615	-1,439	8,666	17,214	24,437
Mild Hybrid	-12,949	-29,209	-31,163	-30,937	-29,696
Full Hybrid	-19,391	-50,933	-62,548	-67,607	-68,851
NAS Path 3	-10,284	-24,688	-28,451	-30,159	-30,435

\* Includes the net of the increase in vehicle costs and the savings in fuel expenditures, minus the loss in excise tax revenues. Does not include environmental benefits.

**Table 1A-11. Net Direct Benefits\* for \$1.81/Gallon Gasoline Price**

<b>Present Value Direct Net Benefits (5% discount rate, million 2001\$)</b>					
<b>Case</b>	<b>2002-2010</b>	<b>2002-2020</b>	<b>2002-2030</b>	<b>2002-2040</b>	<b>2002-2050</b>
Moderate	-2,328	7,540	22,318	34,122	43,933
Advanced	-3,745	6,593	24,221	38,580	50,335
Mild Hybrid	-11,913	-19,593	-12,443	-5,154	1,549
Full Hybrid	-18,241	-40,225	-41,649	-38,317	-32,766
NAS Path 3	-9,530	-17,763	-15,107	-11,878	-8,272

\* Includes the net of the increase in vehicle costs and the savings in fuel expenditures, minus the loss in excise tax revenues. Does not include environmental benefits.

**Technology Cost Estimates.** The technology costs used in this work are based on estimates derived by the NRC, ACEEE and EEA. Each of these estimates represents careful, thoughtful analysis. However, the long-term nature of these forecasts results in a significant degree of uncertainty in the technology costs used in this examination. The economic impacts calculated in this effort are, not surprisingly, highly dependent upon the assumed cost of improved fuel economy.

The studies were consulted to minimize this uncertainty by examining a range of costs. This effort presents this range as an attempt to bracket potential costs and benefits. It is likely that the actual range of technology costs is narrower than those presented here, as industry innovation is difficult to predict. This is especially true for the most advanced fuel efficiency technologies like full hybrids since cost estimates for this technology are “best guesses” today.

The implications of these shifts in technology cost, however, are obvious. Lower technology costs not only mean higher “net” benefits, but they also lead to broader technology use and introduction.

**Vehicle Payback Period.** This section addresses technology costs and fuel savings from the perspective of an individual vehicle purchaser, with a higher expected discount rate of 12 percent. Table 1A-12 illustrates the fuel savings and payback periods for midsize and standard SUV vehicles for the FUTURES scenarios, with 15,000 miles of travel in their first year of use. The payback periods in this table assume that both vehicles are driven less with each successive year, consistent with statewide VMT trends. As a result, both annual VMT and fuel savings, decrease relative to those found in the first year of operation.

Table 1A-12 shows that vehicles with lower fuel consumption tend to be less cost-effective, as lower levels of fuel use correspond to diminished economic benefits in terms of consumer fuel expenditures. The midsize vehicle shown above would break even (i.e. incremental costs are recovered by decreased fuel purchases) within four years, with either ACEEE-Moderate or ACEEE-Advanced technology package. The other technology options would save more fuel than the Moderate or Advanced vehicles, but their incremental costs are not fully recovered.

**Table 1A-12**

<b>Vehicle &amp; Technology</b>	<b>VMT first year</b>	<b>On-Road FE</b>	<b>Savings gal in first year</b>	<b>Inc. Cost \$/vehicle</b>	<b>Payback years</b>
Midsize					
Baseline	15,000	22.0			
Moderate	15,000	34.3	245	1,000	3
Advanced	15,000	38.4	293	1,300	4
Mild Hybrid	15,000	44.2	343	3,500	-
Full Hybrid	15,000	49.7	381	5,100	-
NRC Path 3	15,000	33.5	235	3,200	-
Standard SUV					
Baseline	15,000	13.8			
Moderate	15,000	21.0	372	1,500	3
Advanced	15,000	24.6	476	2,500	5
Mild Hybrid	15,000	28.8	567	4,300	9
Full Hybrid	15,000	32.4	624	6,300	-
NRC Path 3	15,000	22.8	429	3,200	9

For a higher-fuel-consumption vehicle, illustrated here as a hypothetical standard SUV, fuel economy is more cost effective. This stems from incrementally larger savings in fuel expenditures, and therefore larger economic benefits. Table 1A-12 shows that all technology options, except ACEEE-Full Hybrid, break even within ten years of introduction.

**Fuel Economy versus Fuel Consumption.** There is a subtle difference between fuel economy and fuel consumption, particularly with respect to different vehicle classes. The obvious implication of this observation is that a given percentage improvement in fuel efficiency results in larger savings for vehicles with higher fuel use. Table 1A-13 shows two hypothetical examples of fuel savings associated with increased fuel economy for different vehicles.

As seen in this table, Vehicle 1 has a higher fuel economy than Vehicle 2, but the fuel savings associated with increasing the fuel economy of Vehicle 2 are greater than implementing similar improvements in Vehicle 1. In terms of minimizing petroleum consumption, targeting fuel economy improvements in high fuel use vehicles should be a priority.

**Table 1A-13: Illustration of Fuel Savings for Vehicles with Different Fuel Use**

<b>Fuel Economy Improvements</b>	<b>FE mpg</b>	<b>Mileage mi/yr</b>	<b>Fuel Use gal/yr</b>	<b>Savings gal/yr</b>
A 20% FE increase . . .				
Vehicle 1	25	15,000	600.0	—
Vehicle 1 (w/improved FE)	30	15,000	500.0	100.0
Vehicle 2	16	15,000	937.5	—
Vehicle 2 (w/improved FE)	19.2	15,000	781.3	156.3
A 5 mpg FE increase . . .				
Vehicle 1	25	15,000	600.0	—
Vehicle 2 (w/improved FE)	30	15,000	500.0	100.0
Vehicle 2	16	15,000	937.5	—
Vehicle 2 (w/improved FE)	21	15,000	714.3	223.2

<sup>1</sup> “Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards”, NRC

<sup>2</sup> “Technical Options for Improving the Fuel Economy of U.S. Cars and Light Trucks by 2010-2105”, ACEEE

<sup>3</sup> “Preliminary Analysis of Performance and Cost of Electric Hybrid Vehicles”, Energy and Environmental Analysis, Inc., 2001.

<sup>4</sup> One criticism of measures designed to improve fuel efficiency has been that consumers are more interested in higher vehicle performance than they are in fuel efficiency gains so, therefore, to the extent that increased fuel efficiency comes at the expense of performance, consumers would be worse off under such as measure.

<sup>5</sup> EMFAC is an engineering model employed by ARB to track vehicle use and emissions. For further information on the EMFAC model, see California Air Resources Board Staff Report, "Public Meeting to Consider Approval of Revisions to the State's On-Road Motor Vehicle Emissions Inventory," May 2000. Or you can consult ARB's Website at <http://www.arb.ca.gov/msei/msei.htm>.

<sup>6</sup> There are likely to be other effects on vehicle attributes that may impose costs or provide additional benefits to buyers. The effect of changes in vehicle performance levels is considered in the CALCARS simulation.

<sup>7</sup> There may well be effects not captured here; for example, vehicle weight reductions. In providing a revised set of vehicle attributes for this analysis, EEA assumed that higher fuel economy requirements induce manufacturers to reduce slightly the weight of some models to improve fuel efficiency, and weight is not included as a vehicle characteristic in CALCARS. Therefore, to the extent that vehicle owners value weight as an attribute, the estimated net benefits of higher fuel economy may be overstated. As another example, manufacturer efforts to improve fuel economy may involve the use of composite materials that can potentially prolong the life of a vehicle.

## **Option 1B**

### **Fuel-Efficient Replacement Tires and Tire Inflation**

**(Analysis by David Ashuckian)**

#### **Description**

This option seeks a reduction in fuel consumption through greater use of low-rolling resistance replacement tires and through better monitoring of tire inflation pressures. This result would be achieved through a consumer education program on 1) energy efficiency performance of tires and 2) the benefits of using low-rolling resistance replacement tires and for keeping tires properly inflated. Additionally, to increase the result from this option consumers could be provided tire pressure measuring devices and minimum tire efficiency standards could be adopted.

#### **Background**

Vehicle tires that are under-inflated result in increased energy consumption. According to a recent survey by the National Highway Transportation Safety Administration,<sup>1</sup> 27 percent of passenger cars and 32 percent of light trucks are driven with one or more substantially under-inflated tires. Under-inflated tires are defined as at least 8 pounds per square inch (psi) below manufacturer's recommended pressure, which is 25 percent below common recommended inflation pressure of 32 psi. According to the Environmental Protection Agency,<sup>2</sup> one tire under-inflated by 2 psi will result in a 1 percent increase in vehicle fuel consumption.

The use of vehicle tires with low rolling resistance can also reduce energy consumption. According to the American Council for an Energy Efficient Economy,<sup>3</sup> low-rolling resistance tires are introduced as original equipment to help meet Corporate Average Fleet Economy standards in new vehicles. Low-rolling resistance tires can reduce the negative effect of friction by up to 20 percent,<sup>4</sup> providing a fuel economy improvement of 3 to 4 percent without compromising vehicle safety and handling.

Because tires are not currently labeled with energy related information and consumer information on this subject is also lacking, consumers are unaware of the fuel consumption implications of their choices for purchasing replacement tires. Consequently, consumers purchase many after-market replacement tires that result in greater energy consumption compared to the results from original equipment tires.

The Natural Resources Defense Council (NRDC) estimates the energy savings from fuel-efficient replacement tires could approach 5.4 billion barrels of oil over the next 50 years, the equivalent of 70 percent of the total oil available from the Arctic Refuge in Alaska.<sup>5</sup>

Senate Bill 1170 (Chapter 912, Statutes of 2001) directs the Energy Commission to evaluate ways to increase automotive fuel-efficiency in the state government's motor vehicle fleet by 10 percent. This legislation directs the Energy Commission and the State Department of General

Services to study the potential fuel-economy improvements possible through state government purchase of fuel-efficient vehicles and tires.

### **Assumptions and Methodology**

Based on National Transportation Safety Administration data and the relationship of rolling resistance, tire pressure, and increased fuel economy, NRDC estimates that if all tires were properly inflated, on-road passenger vehicle fuel consumption would decrease by about 2 percent.<sup>6</sup> Staff assumes that a consumer education campaign on tire inflation could result in a 50 percent increase in vehicles with proper tire inflation.

In this analysis, based on the life of average tires, and data obtained from Michelin on the rolling resistance of tires,<sup>7</sup> staff assumes that approximately 60 percent of the on-road vehicle fleet have replacement tires, and that 80 percent of those vehicles have tires that are not low-rolling resistance tires.

#### **1. Low-rolling resistance tires.**

##### *Costs*

- Minimum estimated annual cost for a public outreach campaign is \$4 million
- Annual cost of establishing tire rating and labeling system and tire testing is \$1 million
- Estimated cost per vehicle for low-rolling tires: \$40/vehicle/3-years

##### *Benefits*

- Annual vehicle fuel savings based upon annual mileage of 12,500 miles, vehicle fuel economy of 21 miles per gallon gasoline, and a fuel economy improvement of 4 percent. Gasoline price varied plus or minus \$.17 per gallon from the base case forecast of \$1.64 per gallon (one standard deviation in the monthly average retail price over the most recent 5 calendar year period).
- Annual vehicle reduction in fuel use = 21.98 gallons
- Annual fuel savings per vehicle = \$32.31 to \$39.78

##### *Estimate for the Net Consumer Benefits, Government Revenues, and Non-environmental Direct Benefits*

- Prior to the education campaign, low rolling resistance tires were sold with little or no knowledge regarding the fuel economy benefit of the tires. Because of the campaign, the number of units sold would increase and all buyers would recognize that the low rolling resistance tires have increased utility. All of the buyers now understand that the tire provides additional benefits for what they were willing to pay. Thus, from a societal perspective, the net consumer benefits have increased (greater utility per unit cost). At a minimum, the net consumer benefit could be equal to the net present value of total life cycle (3 years) fuel savings and the total incremental cost for the tires.
- Government Revenues would decrease due to reduced collection of fuel excise tax and sales taxes.

- Non-environmental Direct Benefits would be the Net Consumer Benefits minus the costs for the education campaign and the government revenue loss.

## 2. Proper air inflation for tires.

### *Costs*

- Minimum estimated annual cost for a public outreach campaign is \$4 million
- Cost to consumer to for each vehicle: \$0.00 (Zero)

### *Benefits*

- Annual fuel reduction: 11.43 gallons (2% fuel savings)
- Annual fuel savings value: \$16.80 to \$20.69

### *Estimate for the Net Consumer Benefits, Government Revenue, and Non-environmental Direct Benefits*

- The Net Consumer Benefits is equal to the net present value of the fuel savings and incremental tire cost.
- The Government Revenue impact is the present value loss in fuel taxes and the present value cost of the education campaign.
- The Non-environmental Direct Benefits is the sum of Net Consumer Benefits and the Government Revenue impact.

## Results

Combined Low Rolling Resistance Tires and Tire Inflation	Annual Petroleum Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	190	213	249
Reduction From Base Case Demand (percent)	1.12	1.12	1.11

\*Gasoline displacement.

**Table 1B-1. Present Value (2002 Benchmark) of Direct Net Benefits of Low Rolling Resistance Tires and Tire Inflation (millions 2001\$)**

Time Period	Net Consumer Benefits (A)	Government Revenues (B)	Non-Environmental Net Direct Benefits (A+B)
2002-2010	2,111	-705	1,405
2002-2020	3,827	-1,269	2,559
2002-2030	5,034	-1,661	3,373

## Key Drivers and Uncertainties

The key drivers in this analysis are the cost of low-rolling replacement tires, and the increase in fuel economy from this measure. There is uncertainty in the estimated number of vehicles that are currently using less efficient replacement tires. There is also uncertainty in the retail price

consumers would pay for low-rolling resistance tires, and uncertainty in the number of vehicles that operate with improperly inflated tires.

If the TREAD Act<sup>8</sup> requires manufacturers to provide inflation pressure monitoring devices in new vehicles, additional fuel economy gains can be expected. Inflation monitoring devices will provide for additional penetration of properly inflated tires that is not included in the base case forecast or this analysis. The expected penetration level could eventually reach 100 percent, resulting in an additional 1 percent reduction in fuel use. However, this additional reduction would not occur until the California vehicle population was replaced with model year vehicles after the TREAD Act implementation date. This would likely occur in the 2020 to 2030 time frame.

---

<sup>1</sup> U.S. Department of Transportation National Highway Traffic Safety Administration, Consumer Information regulations Uniform Tire Quality Grading Standards, 60 Fed. Reg. 27472 (May 1995).

<sup>2</sup> United States Environmental Protection Agency Website, [www.fueleconomy.gov](http://www.fueleconomy.gov), 2002

<sup>3</sup> John DeCicco, American Council for an Energy-Efficient Economy, Facsimile, July 11, 2000.

<sup>4</sup> K.G. Duleep, National Highway Transportation Safety Administration Docket, August 1995

<sup>5</sup> "A Responsible Energy Policy for the 21<sup>st</sup> Century" National Resources Defense Council March 2001

<sup>6</sup> Roland Hwang, National Resources Defense Council calculations via e-mailed Spreadsheet, March 2002

<sup>7</sup> Michelin, August 9, 1994.

<sup>8</sup> National Highway Transportation Safety Administration, "TREAD Milestones", [www.nhtsa.dot.gov/cars/rules/rulings/tread/MileStones/index.html](http://www.nhtsa.dot.gov/cars/rules/rulings/tread/MileStones/index.html).

## **Option 1C**

### **Government Fleets**

**(Analysis by David Ashuckian)**

#### **Description**

This option would require all government fleets in California, including local, state, and federal fleets to purchase the most fuel-efficient vehicle in each class. The petroleum reduction estimates include all government fleets as well as emergency service pursuit vehicles.

#### **Background**

Based upon descriptions of vehicle size, carrying capacity, or utility, light-duty vehicles are placed in different vehicle classes. This categorization simplifies the marketing and the purchase of vehicles since buyers can immediately screen the number of potential vehicle models to those in the vehicle class of interest. Within each class, a range of fuel economy performance is usually found among the vehicles offered for sale. Thus, if the most efficient gasoline vehicle available in class were always selected for purchase, a fleet owner would likely reduce fuel consumption without sacrificing any utility needs.

There are currently 231,000 light-duty vehicles in government fleets in California; approximately 41,000 of those are in the State of California's own fleet. Based on the historic growth rate of 2 percent per year,<sup>1</sup> there are expected to be 276,000 government fleet vehicles operating in California in 2010.

These vehicles have historically been purchased to satisfy the needs of each agency and to meet the requirements of the national Energy Policy Act (EPAAct) of 1992. Currently, EPAAct requires federal and state fleet operators to replace 75 percent of all new vehicles with vehicles that are capable of operating on an alternative fuel. The desired outcome is a reduction in the use of petroleum fuels. However, there is no requirement that these fleets use an alternative fuel, resulting in little or no reduction in petroleum use. In addition, emergency vehicles, local government vehicles, and vehicles that have a gross vehicle weight over 8,500 pounds are exempt from EPAAct requirements. However, using the most fuel-efficient vehicle available in class may result in greater petroleum fuel reduction than produced by EPAAct requirements. Additional data from fleets is required in order to provide a more accurate estimate of the petroleum reductions that would be achieved from this measure.

#### **Assumptions and Methodology**

Government fleet vehicles are generally replaced at a rate of 10 percent per year.<sup>2</sup> By 2010, all government fleet vehicles could be replaced with vehicles that obtain the best fuel economy in their class.

The average fuel economy for model 2001 passenger cars and light-duty trucks is approximately 21 miles per gallon (mpg), as calculated from the Environmental Protection Agency Model Year Fuel Economy Guide.<sup>3</sup> Based on current availability, the “most efficient vehicle in class” is approximately 28 percent more efficient than the average vehicle in class as determined by staff, if government fleets purchased only the most efficient light-duty vehicles in each class, the average fuel economy of government fleet vehicles could be increased to 27 mpg. At an average rate of 12,500 miles driven per year, and assuming 50 percent of this fleet are vehicles that could be shifted to the best in class, this increase in fuel economy would result in fuel savings of 19 million gallons per year in 2010. A more accurate estimate can be calculated once actual vehicle model data from government fleets is obtained.

#### *Costs*

- No cost impact to consumers. No cost assumed for government.

#### *Benefits*

- Annual fuel reduction
- Annual fuel savings value (2002-2010, 2002-2020, 2002-2030). Annual vehicle fuel savings based upon annual mileage of 12,500 miles, vehicle fuel economy of 21 miles per gallon gasoline, and a fuel economy improvement of about 28.6 percent (21 mpg to 27 mpg). Gasoline price varied plus or minus \$.17 per gallon from the base case forecast of \$1.64 per gallon (one standard deviation in the monthly average retail price over the most recent 5 calendar year period).
- Annual vehicle reduction in fuel use = 158.7 gallons
- Annual fuel savings per vehicle = \$233.29 to \$287.25

#### *Estimate for the Net Consumer Benefits, Government Revenues, and Non-environmental Direct Benefits*

- Net Consumer Benefits will equal the present value of fuel savings.
- Government Revenue impact will be equal to the present value loss in fuel taxes.
- Non-environmental Direct Benefits will be the sum of Net Consumer Benefits and Government Revenues.

#### **Results**

	<b>Annual Petroleum Reduction</b>		
	<b>2010</b>	<b>2020</b>	<b>2030</b>
Strategy Results (millions of gallons)*	19	27	33
Reduction From Base Case Demand (percent)	0.21	0.27	0.29

\*Gasoline displacement.

**Table 1C-1. Present Value (2002 Benchmark) of Direct Net Benefits of Government Fleets (Purchasing Best-in-Class Fuel Efficient Vehicles)**

	<b>Net Consumer Benefits (A)</b>	<b>Government Revenues (B)</b>	<b>Non-Environmental Net Direct Benefits (A+B)</b>
<b>Time Period</b>	<b><i>D</i>=5 Percent</b>	<b><i>d</i>=5 Percent</b>	<b><i>d</i>=5 Percent</b>
2002-2010	N/A	517	517
2002-2020	N/A	954	954
2002-2030	N/A	1,281	1,281

*Costs*

- Average vehicle cost of \$2,400 less than an average vehicle in each class.

*Benefits*

- Present value fuel savings (2002-2010, 2002-2020, 2002-2030)

*Change in Consumer Surplus*

- Change in out-of-pocket cost-benefits: fuel savings
- Change in non-out-of-pocket cost-benefits: little or no loss in vehicle utility except those effected by choice (specific make; perceived or real reliability, durability, dealer service, other intangibles): change assumed negligible

**Key Drivers and Uncertainties**

Uncertainties include a required revision of EPA requirements to allow the purchase of fuel efficient gasoline vehicles in place of EPA qualifying alternative fueled vehicles. There is uncertainty in the number of flexible fuel or dual fuel vehicles in government fleets that currently use an alternative fuel. Other uncertainties include fleet operators' interest in purchasing the most fuel-efficient vehicle in class over a vehicle that may have other desirable attributes. There is also uncertainty regarding the number of light-duty vehicles in the government fleet, and willingness of emergency service and police departments to purchase fuel-efficient pursuit vehicles which have historically been exempt from federal and state purchasing policies.

<sup>1</sup> California Department of Motor Vehicle Data, 2001.

<sup>2</sup> Discussion with Department of General Services, Office of Fleet Procurement staff, November 2001.

<sup>3</sup> United States Department of Energy, Model Year 2002 Fuel Economy Guide, DOE/EE-0250

## **Option 1D**

### **Vehicle Maintenance Practices**

**(Analysis by Dan Fong)**

#### **Description**

This option involves a State campaign to educate motorists on the benefits of improved maintenance practices to reduce the future demand for gasoline consumption. Based upon existing and projected vehicle populations and other parameters and assumptions, estimates of gasoline demand reduction are calculated through 2030.

#### **Background**

In the short-term, improving the efficiency performance of California's vehicle population can be achieved by focusing on vehicle related measures that do not require the time of technology advancement and can be initiated solely through individual or State action. In general, these actions might include periodic engine tune-ups, engine lubrication, changes of air and oil filters, and proper tire inflation levels. However, it is likely that engines in California vehicles that are not operating well are being identified through the State's Smog Check Program. Thus, a large fraction of vehicles that could improve fuel economy performance through a tune-up are already accounted for as part of the base case demand forecast. The potential impact of maintaining proper tire inflation is being evaluated under a separate analysis related to tire replacement and maintenance. Thus, the estimated fuel reduction from improved vehicle maintenance practices will focus on periodic changing of engine lubrication and air and oil filters.

The U.S. Department of Energy estimates that air filter and oil related maintenance practices can improve individual vehicle fuel economy by the percentages shown in Table 1D-1.

**Table 1D-1. Vehicle Maintenance Practices and Fuel Economy**

<b>Action</b>	<b>Potential Fuel Economy Improvement<sup>1</sup></b>
Air Filter Change	1 to 10%
Oil and Oil Filter Change	1 to 2%

#### **Assumptions and Methodology**

Assumptions for the analysis include the following:

Assumptions		
	Measure	Value
1. Individual vehicle fuel economy improvement, %	Air Filter Change	2
	Oil and Filter Change	2
2. Cost	Air Filter Change	\$15 (biennial)
	Oil and Filter Change	\$25 (annual)
3. The air filter would be changed every other year (\$15/filter). <sup>2</sup> Oil and filter changes would occur twice a year (about \$5.50/filter, \$1.35/quart of oil, 5 quarts/oil change). <sup>2</sup>		
4. Survey data from the Car Care Council <sup>3</sup> indicates that in 2000 10% of the vehicle population has an air filter requiring replacement and 20% of the vehicle population has exceeded their oil and filter change interval. These values were used to calculate the upper bound fraction of the fleet population (opportunity fleet) that might contribute to improved fuel economy.		
5. An education campaign was assumed to influence 50% of the opportunity fleet to perform more periodic oil and filter and air filter changes. A more accurate estimate will likely require actual market testing to determine the percentage of consumers influenced by a campaign and its related investment level.		
6. A consumer education campaign to inform motorists on the benefits of improved maintenance practices was assumed to have an annual cost of \$4 million. The cost was separately assumed for each of the maintenance categories. A more accurate cost estimate will likely require actual market testing to determine a limiting cost-benefit ratio.		
7. Although changing an extremely clogged air filter might improve fuel economy by 10%, these opportunities are assumed to be captured by the Smog Check Program. Thus, a relatively modest improvement of 2% is assumed for this analysis.		
8. The opportunity fleet population is a subset of the projected light-duty vehicle fleet from the Base Case CALCARS model for the years 2002 through 2020. Values beyond 2020 were extrapolated from the projected trends.		
9. Gasoline Price = \$1.64 per gallon (base case forecast); Std. deviation of +/- \$.017 per gallon		
10. A discount factor of 0.05 (5 percent) was employed for the cost-benefit results.		

### *Fuel Reduction Calculation*

$R$  = Reduction in Gasoline Demand

$D$  = Original Gasoline Demand (consumption before fuel economy improvement)

$x$  = fuel economy improvement, percent/100

$$R = \left(1 - \frac{1}{1 + x}\right)(D)$$

Example: Calculate the reduction in gasoline demand for a 10% fuel economy improvement and an original demand of 100 gallons.

$$\begin{aligned}
 R &= \left(1 - \frac{1}{1 + 10/100}\right)(100) \\
 &= 9.09 \text{ gallons reduced demand}
 \end{aligned}$$

### Costs

- Air Filter Changes: (\$15 per vehicle every other year) x (Fleet Population) x (10%) x (0.5)
- Oil and Oil Filter Changes: (\$25 per vehicle annually) x (Fleet Population) x (20%) x (0.5)
- Education Campaign: \$4 million annually for each measure

### Benefits

- Annual fuel savings = (\$1.64/gallon) x (Annual Reduction)

### Net Consumer Benefits, Government Revenue Impact, Non-Environmental Net Direct Benefits

- A. Annual Net Consumer Benefits = (Value of annual gasoline reduction) – (Annual Maintenance Expense), \$
- B. Annual Government Revenue Impact = Annual Cost of Education Campaign + Reduced Fuel taxes + Increased Sales Tax (filters and oil), \$ (negative if revenue declines or funds expended)
- C. Non-Environmental Net Direct Benefits = A + B = C, \$

Present Value of Net Direct Benefits = Present Value of Net Consumer Benefits + Present Value of Government Revenue Impact =

$$\sum_{n=0}^t \frac{(A)_n}{(1+d)^n} + \sum_{n=0}^t \frac{(B)_n}{(1+d)^n}$$

where  $d$  = discount rate (0.05);  $n$  = years from the base year: 0, 1, 2, 3, ...,  $t$ ;  $t$  is the last year from the base year; the base year is 2002

**Table 1D-2. Present Value (2002 Benchmark) of Net Direct Benefits of Vehicle Maintenance Practices (millions 2001\$)**

Measure	Time Period	Net Consumer Benefits (A)	Government Revenues (B)	Non-Environmental Net Direct Benefits (A+B)
Air Filter Change	2002-2010	112	-59	53
	2002-2020	209	-104	105
	2002-2030	278	-134	144
Oil and Filter Change	2002-2010	-79	-65	-144
	2002-2020	-145	-115	-260
	2002-2030	-194	-148	-342

The present value of net consumer benefits and non-environmental net direct benefits is controlled by the cost of the fuel economy measure and the related fuel economy improvement. The assumed cost of the education campaign was a minor element in the calculation; this annual cost was much smaller than the other cost terms in the summation of costs (negative values) and benefits (positive values).

The oil and filter change did not produce a positive net consumer benefit due to its annual consumer cost and relatively small fuel economy impact. The air filter change produced a positive net consumer benefit because its cost occurred every other year while and its fuel

savings offset this cost. Furthermore, the air filter option also produced a positive non-environmental net direct benefit.

Due to the reduced sale of gasoline from improved energy efficiency, revenue from fuel excise taxes and sales taxes decline. This revenue impact is somewhat reduced by the increased sales of air filters and oil and oil filters. However, since fuel excise taxes are generally greater in magnitude than sales taxes, the net government revenue is negative.

## Results

Result	Measure	Year		
		2010	2020	2030
Annual Reduced Gasoline Consumption (million gallons)	Air Filter Change	17	19	22
	Oil and Filter Change	34	38	44
	Total	51	57	66
Total Reduction From Base Case Demand (percent)		0.3	0.3	0.3

## Key Drivers and Uncertainties

- The reduction in petroleum fuel demand is linearly dependent on the number of vehicle operators influenced by the media campaign. The reduction result would double if the fraction of the opportunity fleet responding to the media campaign increased to 100 percent from 50 percent. Conversely, the value would decrease by half if 25 percent of the opportunity fleet adopted the practice.
- The sign of the net direct benefits result (positive or negative) depends on the magnitude of the fuel economy improvement and related expenditure. The air filter change produced a positive result because its cost, \$15 per vehicle every other year, would be offset by the value of fuel savings. The cost of the oil and filter changes was \$25 per vehicle annually and was not offset by the value of annual fuel savings.

<sup>1</sup> [www.fueleconomy.gov/feg/maintain.shtml](http://www.fueleconomy.gov/feg/maintain.shtml), November 2001.

<sup>2</sup> Informal survey of retail prices for filters and oil at auto parts store, Dan Fong, California Energy Commission, November 2001.

<sup>3</sup> [www.carcarecouncil.org](http://www.carcarecouncil.org), National Car Care Month Inspections, 1996-2000, November 2001.

## **Option 1E**

### **Light-Duty Diesel Vehicles**

**(Analysis by Dan Fong and Gary Yowell)**

#### **Description**

The use of diesel in light-duty vehicles (LDV) that typically use gasoline was examined to determine the potential to reduce gasoline and petroleum use. Light-duty vehicles weighing up to and including 10,000 pounds were evaluated.

#### **Background**

Because of its combustion characteristics, diesel fuel can be used in a compression ignition engine. This type of engine has a potential energy efficiency that is greater than a gasoline fueled engine. Since diesel has become the preferred fuel for use in a compression ignition engine, the engine is now commonly called a diesel engine.

Based upon work and analyses performed by the U.S. Department of Energy (DOE), the technology prospects for light-duty diesels are advancing. Table 1E-1 is adapted from information<sup>1</sup> that compares projected vehicle cost and fuel economy levels for different gasoline and diesel light-duty vehicle sizes. The diesel engine technology used in the comparison was compression ignition, direct injection (CIDI). Although the baseline vehicle used in the comparison was a 1996 model year vehicle in the size classes shown, the prices that are displayed have been adjusted to 2001\$.

The incremental vehicle price includes the cost difference between a diesel and gasoline engine. Based upon a current price comparison between a diesel Volkswagen Jetta and its gasoline counterpart, the vehicles' price difference is about \$900. Since the DOE price projection for a small car is only \$1,100, these prices appear to not fully include the potential price impact of additional emission controls needed to meet California emission standards and are more indicative of just the price difference between a diesel and gasoline engine.

For the diesel vehicles examined, the projected fuel economy improvement over a comparable gasoline vehicle was expressed as the volumetric fuel economy ratio, ranging from 1.35 to 1.4 in mature time frame years of 2008-2010. However, a gallon of diesel fuel contains about 12.5 percent more energy compared to a gallon of gasoline. Thus, the projected energy efficiency ratio for a diesel engine compared to a gasoline engine is in the range of 1.22 to 1.28.

The fuel economy ratios in Table 1E-1 have been reduced to account for the effects of additional emission controls. According to an estimate from the Argonne National Laboratory,<sup>2</sup> a three-percent fuel economy penalty can be assumed for a California specific diesel vehicle compared to a non-California diesel. Thus, the ratios in the table would decrease by about 0.05, leaving a volumetric fuel economy improvement range of 1.3 to 1.35. The projected energy efficiency ratios are also decreased to 1.14 to 1.24.

**Table 1E-1. Direct Injection Diesel Vehicles and Comparable Gasoline Vehicles<sup>3</sup>**

Vehicle Size	Fuel	1) Introduction Year 2) Maturity	Vehicle Price, \$ <sup>4</sup>	Adjusted Volumetric Fuel Economy, <sup>5</sup> mpg	Adjusted Volumetric Fuel Economy <sup>6</sup> Ratio Compared to Gasoline	Adjusted Energy Efficiency Ratio Compared to Gasoline <sup>7</sup>
Small Car	Diesel	1) 2003	17,300	42.5	1.35	1.19
		2) 2008	17,300	42.5	1.35	1.19
	Gasoline	1996	16,200	31.3	1.0	1.0
Large Car	Diesel	1) 2005	27,200	34.0	1.30	1.14
		2) 2010	26,700	34.0	1.30	1.14
	Gasoline	1996	25,400	25.9	1.0	1.0
Sport Utility Vehicle	Diesel	1) 2004	25,100	29.7	1.40	1.24
		2) 2009	24,900	29.7	1.40	1.24
	Gasoline	1996	23,300	21.1	1.0	1.0
Minivan	Diesel	1) 2004	26,000	31.9	1.40	1.24
		2) 2009	25,800	31.9	1.40	1.24
	Gasoline	1996	24,100	22.7	1.0	1.0
Pickup Trucks, Large Vans	Diesel	1) 2002	18,100	25.5	1.30	1.14
		2) 2007	17,600	25.5	1.30	1.14
	Gasoline	1996	16,400	19.5	1.0	1.0

Technologies are now being developed and evaluated as potential emission control measures for advanced diesel engines. For the purpose of this analysis, estimates of the additional cost due to these technologies have been extrapolated from projected costs made by the U.S. Environmental Protection Agency. The California Air Resources Board then adjusted these estimates for diesel engines used in large trucks (light-heavy, medium-heavy, and heavy-heavy trucks).<sup>8</sup> The published estimates of vehicle incremental price were \$2,095, \$2,705, and \$3,405 for light-heavy, medium-heavy, and heavy-heavy diesel trucks, respectively.

These values were then extrapolated to smaller engine sizes over the range of 2 to 5 liters. The smaller engine sizes are typical of those used in light-duty diesel vehicles. The result from this extrapolation provides an incremental price range of \$1,000 (2-liter engine) to \$1,725 (5-liter engine) for the emission control systems. These prices can be added to the price difference between a diesel and gasoline engine to obtain an incremental vehicle price, as shown in Table 1E-2.

**Table 1E-2. Differential Price Between a Diesel Vehicle and Gasoline Vehicle**

Vehicle Size	Higher Diesel Engine Cost Compared to Gasoline Engine, \$	Diesel Engine and Emission Control Price Difference, \$
Small Car	1,100	2,100
Large Van (5 Liter engine)	1,700	3,425

Debate exists as to whether emission control technology can be developed to enable light-duty diesel vehicles to meet California's 2007 exhaust emission standards. Industry representatives have stated they will be able to develop satisfactory technology when used with expected low sulfur diesel (15 ppm sulfur), while public health advocates emphasize that no engines have been

certified at this time and that future technologies and emission reductions are still uncertain. It is outside the scope of this Task 3 report to resolve the need for future debate. In the simplest terms, if manufacturers are unable to meet requirements, vehicles will not be sold. If current emission standards are found inadequate to protect health, they will be strengthened, and diesel technologies may or may not meet them. Further discussion of emission regulations follows at the end of this section.

Due to a variety of market constraints, light-duty diesel vehicles in California have historically experienced low sales when compared to gasoline vehicles. Table 1E-3 shows the relative market size and population of diesel vehicles in California for the vehicle classes approximated in this analysis.<sup>9</sup> With the exception of vans and heavier pickups (8,501 – 10,000 lbs. gross vehicle weight), the market share of 2000 model year diesel vehicles in these classes was less than 10 percent. Growth in diesel sales has not occurred in vehicle classes less than 8,500 pounds gross vehicle weight because they have been unable to comply with stringent emission standards. California's light-duty vehicle population, excluding commercial fleets, is currently near 20 million, and only about 300,000 vehicles are registered as diesel fueled.

Even though the current market for light-duty diesels in California seems very limited, policies in Europe (e.g., favorable fuel taxation on diesel fuel and less stringent exhaust emission standards) and vehicle performance improvements have led to a much larger market share for diesels than in California. The 2000 European LDV market share (annual sales) for diesel varies from about 10 percent in the United Kingdom to between 50 and 60 percent in France, Spain, and Austria.<sup>10</sup> Although this example may not be comparable to California due to different economic conditions and uncertainty regarding compliance with emission standards, the potential exists for consumers to choose an increasing proportion of diesel models over comparable gasoline models.

**Table 1E-3. Relative Vehicle Registrations of Selected Light-Duty Diesel Classes in California<sup>11</sup>**

<b>Vehicle Class</b>	<b>Percent of Class 2000 Model Year</b>	<b>Percent of Overall Light-duty Fleet</b>
Cars (compact, mid- & full-size)	0.1	4
Standard Pick Ups	0.8	1.1
Standard Vans	9.2	10
Standard Sport Utility	1.3	0.6
Pickups 8,501-10,000 lbs. GVW	35	22

### **Assumptions and Methodology**

The following scenarios assume that highly efficient NO<sub>x</sub> and particulate matter (PM) after-treatment will be available and used on light duty diesel vehicles beginning in 2007, allowing a growth in sales to occur. Low sulfur diesel fuel will also be available before 2007, as currently required by the U.S. Environmental Protection Agency.

Although this option is categorized as an efficiency measure, the comparison tool that is employed to evaluate the options in the fuel displacement category can also be used to examine

the light-duty diesel option (see Group 2 Variation section in Methodology chapter). To establish a range of outcomes for different costs and fuel economies, two vehicle classes are selected, the small car class and the pickup truck/large van class. The appropriate diesel vehicle is then compared to the equivalent gasoline vehicle. Table 1E-4 shows the values for key parameters that will produce upper and lower bound cases.

**Table 1E-4. Selected Light-Duty Diesel Vehicle Parameters Compared to Gasoline Vehicle**

<b>Vehicle Class</b>	<b>Diesel Incremental Vehicle Cost, \$</b>	<b>Diesel Volumetric Fuel Economy Ratio</b>	<b>Gasoline Vehicle Fuel Economy, mpg</b>
Small Car	2,100	1.35	31.3
Large Van	3,425	1.3	19.5

Based upon the results of a 1998-1999 survey of about 7,500 retail service stations in California, the existing retail infrastructure for dispensing diesel is assumed to be adequate for the projected growth in diesel vehicle population during the first 10 years of the scenarios evaluated.<sup>12</sup> The survey found that about 24 percent of the surveyed sites dispensed diesel fuel. For additional infrastructure beyond this level, the cost of expanding retail fuel stations to dispense diesel is assumed to be absorbed by private industry as a normal investment opportunity, controlled by the economic opportunity of supplying diesel fuel to meet demand. However, as a sensitivity element in the comparison model for the onset of a larger demand for diesel fuel, an incremental infrastructure cost of \$10,000 per station was assumed. This amount would pay for the addition of a dual hose dispenser for diesel.<sup>13</sup>

**Scenario 1: Mature Market (Small Car Case).** The comparison tool employs the incremental cost for the small car class shown in Table 1E-4. The volumetric fuel economy ratio for the small car diesel was 1.35. A discount rate of 5 percent was used to determine net life cycle costs. A 12 percent rate was employed for the additional infrastructure cost. Diesel and gasoline fuel prices that were projected for the base case energy demand forecast were used with a standard deviation of \$.17 per gallon, based upon historical monthly price variations.

The estimate for petroleum fuels reduction is based on an assumption that in 2010, there would be an increase of 4 percent of light-duty diesel vehicles in the vehicle population. In reality, this population level is not reasonably achievable because the introduction of new vehicles would not begin until 2007. This assumption is being made for comparison purposes with other technology based options. An additional assumption is that the diesel fleet population reaches 10 percent in 2020 and is held constant in subsequent years.

## Results

**Table 1E-5. Scenario 1 Gasoline Reduction Results**

	<b>Annual Gasoline Reduction</b>		
	<b>2010</b>	<b>2020</b>	<b>2030</b>
Scenario 1 Results (millions of gallons)*	686	1,952	2,241
Gasoline Reduction From Base Case Demand (percent)	4	10	10
Net Gasoline Reduction (millions of gallons)	92	263	302
Net Gasoline Reduction from Base Case Demand (percent)	0.5	1.3	1.3

\*Gasoline displacement

Although the volume of gasoline displaced seems large due to the replacement of a gasoline vehicle by a diesel vehicle, a more important value is the net gasoline fuel reduction. Over a certain distance, the diesel vehicle will use a volume of diesel fuel based upon its volumetric fuel economy. This volume of diesel fuel must then be converted to an equivalent volume of gasoline based upon the ratio of energies contained within a gallon of each fuel (126,000 Btu/diesel gallon, 112,000 Btu/gasoline gallon). When this equivalent volume is determined, it can be subtracted from the volumetric gasoline displaced to obtain the net gasoline displaced. The net gasoline displaced is more indicative of this option's impact on overall demand for petroleum fuels.

**Table 1E-6. Scenario 1 Mature Market (Small Car) Comparison: Diesel versus Gasoline Counterpart\***

Diesel Vehicle	Gasoline Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost		Life Cycle Overall Cost	
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon Gasoline Displaced	\$/Gallon Net Gasoline Fuel Displaced	\$/Gallon Gasoline Displaced	\$/Gallon Net Gasoline Fuel Displaced
Low	Low	2,100	-\$151	\$933	\$0.27	\$1.62	\$.27	\$1.62
High	High	2,100	-\$185	\$672	\$0.20	\$1.23	\$.20	\$1.23

\*Negative values indicate "savings"

There are two fuel cost conditions used for the life cycle cost comparison. It is likely that the costs of diesel and gasoline are linked. In other words, whenever a low or high cost condition occurs for one, it would also occur for the other.

The comparison shows that for the assumed incremental vehicle cost, the consumer would experience a net cost when compared to owning and operating a gasoline car. Although there would be annual savings in fuel cost, this amount does not offset the incremental cost of the vehicle.

**Table 1E-7. Scenario 1 Mature Market (Large Van) Comparison: Diesel versus Gasoline Counterpart\***

Diesel Vehicle	Gasoline Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost		Life Cycle Overall Cost	
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon Gasoline Displaced	\$/Gallon Net Gasoline Fuel Displaced	\$/Gallon Gasoline Displaced	\$/Gallon Net Gasoline Fuel Displaced
Low	Low	3,425	-217	\$1,752	\$.30	\$2.23	\$.30	\$2.23
High	High	3,425	-265	\$1,382	\$.24	\$1.80	\$.24	\$1.80

\*Negative values indicate "savings"

Since fuel excise taxes are levied on a per gallon basis, a change in fuel excise tax revenue occurs in the comparison between the gasoline and diesel vehicle. The excise taxes applied to

gasoline and diesel are \$.18 and \$.243 per gallon, respectively. This difference and the different volumes of fuel consumed are used to determine the change in revenue.

The present value of the change in excise tax revenue (\$ per vehicle over a 10-year vehicle life, 5 percent discount rate) for the small car case shown in Table 1E-6 is \$144 (the government revenue declines by this amount). A similar change in tax revenue for the large van case shown in Table 1E-7 is \$171 per vehicle. The value is the same for the Low-Low and High-High fuel cost conditions since the volumetric change in fuel that is sold is the same for both cost conditions. The large van case results in a greater excise tax change because this vehicle uses a greater volume of fuel than the small vehicle.

### **Key Uncertainties**

**Market Demand:** There is uncertainty regarding California consumer response to light duty diesel vehicles under 8,500 lbs. gross vehicle weight. Logically, the higher vehicle cost for a diesel would have to be defrayed by its fuel savings to persuade a large fraction of consumers to choose a diesel over a gasoline vehicle. However, gasoline vehicles may also improve their fuel economy, partially offsetting a diesel vehicle's operating cost advantage.

It is possible that future "mature costs" of vehicles meeting much tighter emission standards will be higher than assumed in this analysis. The simultaneous attainment of future strict NO<sub>x</sub> and PM standards represents a major challenge to manufacturers, as there are typically tradeoffs between the control of NO<sub>x</sub> versus PM in diesel cycle engines.

**Truck CAFE:** Corporate average fuel economy (CAFE) regulations may be revised to compel vehicle manufacturers to produce higher fuel economy for standard and compact pickup trucks. To take advantage of their higher fuel economy, manufacturers may offer additional vehicle models with diesel engines, if cost-effective technology can be developed to meet emission standards.

**Emission Regulations:** For light duty vehicles with a gross vehicle weight of less than 8,500 pounds, most of which are passenger-carrying vehicles, emission regulations for HC, CO, and NO<sub>x</sub> have been set based on the lowest achievable emission rate for gasoline vehicles. For diesel engine light duty vehicles to achieve such emissions standards, highly efficient exhaust after-treatment for both NO<sub>x</sub> and PM is required. PM filters have demonstrated the efficiency needed to comply with the California PM standard for light duty diesels, and these filters are being used on some new diesel passenger cars sold in Europe.

The greater challenge for diesel vehicles is the development of NO<sub>x</sub> after-treatment which is durable and of high enough efficiency to comply with the California NO<sub>x</sub> standard. Development efforts are focused on heavy-duty engines, which will require NO<sub>x</sub> after-treatment beginning in 2007. If successful, similar technology can be used on light duty diesel vehicles.

The National Research Council recently concluded the following in its latest assessment of the Partnership for a New Generation of Vehicles:

“The critical issue for the diesel engine continues to be whether the emission standards for NOx and particulate matter can be met. At this point in the program, the prospect of meeting the emission targets with the compression ignition direct injection (CIDI) engine is improving but is still speculative.”<sup>14</sup>

For vehicles with gross vehicle weights in excess of 8,501 pounds, which include many work trucks, emissions standards are more closely tied to the standards for heavy-duty truck engines. This has resulted in emissions standards for heavier pickups and delivery vehicles that can be more readily met by using diesel engines, as evidenced by the substantial number of diesel vehicles being sold in this weight class.

Although the scenario analysis was not able to explicitly account for a PM standard for light-duty diesel vehicles that would change in the future, there is growing evidence of the importance of diesel exhaust, both in terms of mass and the number of particles. Recent health findings based on epidemiological assessment of over 500,000 case histories suggest that there are significant mortality and morbidity effects associated with relatively low level exposures to ambient PM 2.5 (particle size less than or equal to 2.5 microns).<sup>15</sup> It is quite possible that in the next several years, there will be a clear need to increase the stringency of the existing diesel PM standards.<sup>16</sup> If that occurs, auto manufacturers will be challenged further to attain gasoline-equivalent performance, durability and cost characteristics with diesel vehicles designed to meet a more stringent set of emission standards.

The scenarios considered also assume that technology development and breakthroughs will be adequate to ensure full in-use equivalence between diesel and gasoline vehicles. The recent history of diesel in-use emission testing and enforcement, however, suggest that diesel in-use emissions can exceed certification values. Heavy-duty diesel engine manufacturers, for example, have been subject to consent decrees that grew out of excessive non-compliance based on real world in-use testing.<sup>17</sup> Because some advanced NOx control systems, such as urea-based SCR, rely on in-field actions to keep the systems fully functioning, there is greater risk that emissions durability for future diesel control systems will be more uncertain than existing systems.<sup>18</sup> Members of the Engine Manufacturers Association, for example, have recently informed the ARB that they are unable to commit to early demonstrations of advanced diesel emission control systems designed to meet the 2007 heavy duty truck standards.<sup>19</sup> Similar problems may occur in the light- and medium-duty vehicle segment.

**Diesel Fuel Supply.** The scenarios analyzed assumed that the supply of diesel fuel could be increased to meet the projected increase in demand. However, a significant increase in diesel product demand may require substantial changes to refineries which are generally designed to maximize their gasoline production. Diesel production is directly limited by the capacity of desulfurization units such as hydrotreaters, hydrodesulfurization units and fluid catalytic crackers.

The scenario analysis assumes that there will be no loss of efficiency from realignment of the refinery to increase the output of diesel fuel. Refiners are currently planning to adjust their refineries to produce all of their on-road diesel fuel that has less than 15 ppm sulfur. The need

for hydrogen capacity to refine significant added quantities of diesel fuel has not been factored into these plans.

---

<sup>1</sup> U.S. Department of Energy, Program Analysis Methodology, Office of Transportation Technologies, Quality Metrics Final Report 2001, February 23, 2000

<sup>2</sup> Personal communication between Gary Yowell (CEC) and Frank Stodolsky, Argonne National Laboratory, March 14, 2002. For modeling purposes, a 3 percent fuel economy penalty is assumed to be required due to emission controls estimated to meet California emission standards.

<sup>3</sup> U.S. Department of Energy, Program Analysis Methodology, Office of Transportation Technologies, Quality Metrics Final Report 2001, February 23, 2000.

<sup>4</sup> The original 1996 costs were adjusted for inflation and brought to 2001\$. A CEC factor, the GDP Implicit Price Deflator (1998 = 100), was applied to the 1996 vehicle costs. For this case, the factor was 1.0946 (106.23/97.05)

<sup>5</sup> The volumetric fuel economy values for the diesel vehicles have been adjusted to reflect a 3 percent fuel economy penalty due to more stringent emission controls.

<sup>6</sup> The ratios have been adjusted to reflect a 3 percent fuel economy penalty due to more stringent emission controls.

<sup>7</sup> The energy efficiency ratios have been calculated using a 12.5 percent energy difference between diesel and gasoline and the 3 percent efficiency penalty due to more stringent emission controls.

<sup>8</sup> U.S. EPA, Final Regulatory Impact Analysis: Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, December 2000; California Air Resources Board, Staff Report: Initial Statement of Reasons, Consideration of Amendments Adopting More Stringent Emission Standards Control of Emissions of Air Pollution from Highway Heavy-duty Engines, September 2001 (adopted October 2001).

<sup>9</sup> CEC DMV data SUM2000R3.XLS, Gary Occhiuzzo. DMV vehicle registration data for 2000 was extracted by CEC staff to produce the table values.

<sup>10</sup> Ward's Auto World, Super Diesels, The Market, figure on page 39, September 2001.

<sup>11</sup> CEC DMV data SUM2000R3.XLS, Gary Occhiuzzo. DMV vehicle registration data for 2000 was extracted by CEC staff to produce the table values.

<sup>12</sup> CEC used proprietary contractor survey data on about 75 percent of all California retail service stations in 1998-99 and found that about 24 percent of these sites dispensed diesel fuel. These sites were concentrated in cities and urban counties. Thus, the existing accessibility of diesel fuel is not assumed to limit the market growth for diesel vehicles.

<sup>13</sup> Personal Communication between Alan Argentine (CEC) and Dave Wallace, Titan Rubber and Supply, West Sacramento, CA March 2002.

<sup>14</sup> Review of the Research Program of the Partnership for a New Generation of vehicles, Seventh Report, National Research Council, p. 35, 2001. The report further notes the following:

“It is generally agreed that EGR will have to be employed to meet emission standards. Typical engines tend to exhibit a quadratic increase of PM emissions with EGR increase. (p. 25). ... The highest NOx conversion efficiency and the least fuel economy penalty have been achieved using an SCR system with urea as the reductant. Conversion efficiencies of approximately 80 percent over the Federal Test Procedure driving cycle have been obtained with simulated gas feed. This resulted in a projected fuel economy penalty of less than 0.5 percent [emphasis added] (p. 27).”

<sup>15</sup> C. Arden Pope III, et al., Lung Cancer, Cardiopulmonary Mortality, and Long-Term Exposure to Fine Particulate Air Pollution, Journal of the American Medical Association, 2002; 287:1132-1141.

<sup>16</sup> California Air Resources Board, Proposal to Establish a 24-hour Standard for PM2.5, Draft, March 12, 2002, Report to the Air Quality Advisory Committee, <[www.arb.ca.gov/research/aaqs/std-rs/pm25-draft.htm](http://www.arb.ca.gov/research/aaqs/std-rs/pm25-draft.htm)>

<sup>17</sup> U.S. EPA, Office of Regulatory Enforcement Diesel Engine Settlement Information, <<http://us.epa.gov/oeca/ore/aed/diesel/>>

<sup>18</sup> Review of the Research Program of the Partnership for a New Generation of vehicles, Seventh Report, National Research Council, p. 27, 2001.

<sup>19</sup> California Air Resources Board, Status Report, Public Transit Bus Fleet Rule, March 2002. p. 9. <[www.arb.ca.gov/msgrog/bus/StatusReport0221.pdf](http://www.arb.ca.gov/msgrog/bus/StatusReport0221.pdf)>

Option 1E -- Light-Duty Diesel Vehicles (Small Car)

INPUTS

Fleet Information	Units	Diesel Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1,000	Vehicles	1,000
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gallon	42.3	Miles/Gallon	31.3
Fuel Consumption	Gallons/Year	295,823	Gallons/Year	399,361
Daily Consumption	Gallons/weekday	948	Gallons/weekday	1,280

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Diesel Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$2,100	\$2,100	\$0	\$0
Total Incremental Vehicle Cost	\$	\$2,100,000	\$2,100,000	\$0	\$0

Fuel Costs	Units	Diesel		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.818	\$1.474	\$1.810	\$1.470
Annual Fuel Cost	\$/year	\$537,898	\$435,898	\$722,843	\$587,061

OUTPUTS

Diesel Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost Diesel-Gasoline)	Incremental Annual Fuel Cost (Diesel-Gasoline)	Present Value Consumer Costs ("-" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Gasoline Displaced	Present Value Government Cost \$/Gallon Displaced	Present Value Total \$/Gallon Net Gasoline Displaced	Present Value Government Cost \$/Gallon Net Gasoline Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon	\$/Gallon	\$/Gallon
Low	High	\$2,100,000	-\$286,946	-\$115,718	\$143,909	\$143,909	\$0.007	\$0.036	\$0.042	\$0.216
High	Low	\$2,100,000	-\$49,163	\$1,720,375	\$143,909	\$1,864,284	\$0.467	\$0.467	\$2.801	\$2.801
Low	Low	\$2,100,000	-\$151,163	\$932,760	\$143,909	\$1,076,669	\$0.270	\$0.270	\$1.618	\$1.618
High	High	\$2,100,000	-\$184,946	\$671,897	\$143,909	\$815,806	\$0.204	\$0.204	\$1.226	\$1.226

Diesel Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (Diesel-Gasoline)	Incremental Annual Fuel Cost (Diesel-Gasoline)	Present Value Consumer Cost Net Present Value ("-" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$2,100	-\$287	-\$116	\$144	\$144	\$28
High	Low	\$2,100	-\$49	\$1,720	\$144	\$1,864	\$1,864
Low	Low	\$2,100	-\$151	\$933	\$144	\$1,077	\$1,077
High	High	\$2,100	-\$185	\$672	\$144	\$816	\$816

("-" represents savings to user; no government cost)

# Option 1E -- Light-Duty Diesel Vehicles (Small Car)

## INPUTS

Unit

### Fleet Information

Number of Vehicles		1,000
Fuel Consumption	<b>Gallons/Year</b>	295,823
Daily Consumption	<b>Gallons/weekday</b>	948

### Station Owner Information

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

### Capital Costs

Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$10,000
Station Upgrade Expenses (total)	<b>\$</b>	\$10,000

### Other Costs

Revenue From Retail Mark-Up	<b>\$/year</b>	\$0	(assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00	
Gulf Coast to CA LPG Annual Import Cost	<b>\$/year</b>	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

## OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low Fuel Wholesale Cost	\$0.940	\$1,339	\$278,074	\$279,412	\$0.945	\$1.474
High Fuel Wholesale Cost	\$1.260	\$1,339	\$372,737	\$374,076	\$1.265	\$1.818

	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	83,527	112,000
CA Taxes =	\$0.060	\$0.18
Fed Taxes =	\$0.136	\$0.18
Total Exise Taxes =	\$0.196	\$0.42
Sales Taxes =	7.75%	7.75%

## Historical Diesel Prices

cents/gallon			
Annual			
W'sale			
Year	Advanced Diesel	Deflator Index	2002 \$
1984	45.0	67.27	72.7
1985	39.8	69.58	62.1
1986	29.0	71.40	44.1
1987	25.2	73.59	37.2
1988	24.0	76.28	34.2
1989	24.7	79.49	33.8
1990	38.6	82.93	50.6
1991	34.9	86.23	44.0
1992	32.8	88.60	40.2
1993	35.1	90.94	41.9
1994	32.4	93.11	37.8
1995	34.4	95.26	39.2
1996	46.1	97.05	51.6
1997	41.6	98.85	45.7
1998	28.8	100.00	31.3
1999	34.2	101.81	36.5
2000	76.7	103.85	80.2
2001		106.23	
2002		108.64	

Average =	46.07	Cents per gallon
Standard Deviation =	13.79	Cents per gallon
Average Plus Standard Deviation =	\$0.599	Dollars per gallon
Average Minus Standard Deviation =	\$0.323	Dollars per gallon

Mimimum =	\$0.313	(2002\$)
Maximum =	\$0.802	(2002\$)

Option 1E -- Light-Duty Diesel Vehicles (Large Van)

INPUTS

Fleet Information	Units	Diesel Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1,000	Vehicles	1,000
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gallon	25.4	Miles/Gallon	19.5
Fuel Consumption	Gallons/Year	493,097	Gallons/Year	641,026
Daily Consumption	Gallons/weekday	1,580	Gallons/weekday	2,055

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Diesel Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$3,425	\$3,425	\$0	\$0
Total Incremental Vehicle Cost	\$	\$3,425,000	\$3,425,000	\$0	\$0

Fuel Costs	Units	Diesel		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.816	\$1.472	\$1.810	\$1.470
Annual Fuel Cost	\$/year	\$895,640	\$725,620	\$1,160,256	\$942,308

OUTPUTS

Diesel Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (Diesel-Gasoline)	Incremental Annual Fuel Cost (Diesel-Gasoline)	Present Value Consumer Costs ("-" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Gasoline Displaced	Present Value Government Cost \$/Gallon Displaced	Present Value Total \$/Gallon Net Gasoline Displaced	Present Value Government Cost \$/Gallon Net Gasoline Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon	\$/Gallon	\$/Gallon
Low	High	\$3,425,000	-\$434,636	\$68,855	\$171,340	\$240,195	\$0.037	\$0.037	\$0.278	\$0.278
High	Low	\$3,425,000	-\$46,668	\$3,064,645	\$171,340	\$3,235,985	\$0.505	\$0.505	\$3.750	\$3.750
Low	Low	\$3,425,000	-\$216,687	\$1,751,797	\$171,340	\$1,923,138	\$0.300	\$0.300	\$2.229	\$2.229
High	High	\$3,425,000	-\$264,616	\$1,381,702	\$171,340	\$1,553,043	\$0.242	\$0.242	\$1.800	\$1.800

Diesel Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (Diesel-Gasoline)	Incremental Annual Fuel Cost (Diesel-Gasoline)	Present Value Consumer Cost Net Present Value ("-" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$3,425	-\$435	\$69	\$171	\$240	\$240
High	Low	\$3,425	-\$47	\$3,065	\$171	\$3,236	\$3,236
Low	Low	\$3,425	-\$217	\$1,752	\$171	\$1,923	\$1,923
High	High	\$3,425	-\$265	\$1,382	\$171	\$1,553	\$1,553

("-" represents savings to user; no government cost)

# Option 1E -- Light-Duty Diesel Vehicles (Large Van)

## INPUTS

Unit	
Fleet Information	
Number of Vehicles	1,000
Fuel Consumption	Gallons/Year 493,097
Daily Consumption	Gallons/weekday 1,580

<b>Station Owner Information</b>		
ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

<b>Capital Costs</b>		
Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$10,000
Station Upgrade Expenses (total)	<b>\$</b>	\$10,000

Other Costs			
Revenue From Retail Mark-Up	<b>\$/year</b>	\$0	(assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00	
Gulf Coast to CA LPG Annual Import Cost	<b>\$/year</b>	\$0	

## OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low Fuel Wholesale Cost	\$0.940	\$1,339	\$463,511	\$464,850	\$0.943	\$1.472
High Fuel Wholesale Cost	\$1.260	\$1,339	\$621,302	\$622,641	\$1.263	\$1.816

	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	83,527	112,000
CA Taxes =	\$0.060	\$0.18
Fed Taxes =	\$0.136	\$0.18
Total Exise Taxes =	\$0.196	\$0.42
Sales Taxes =	7.75%	7.75%

## Diesel Fuel Prices

cents/gallon			
Annual			
W'sale			
Year	Advanced Diesel	Deflator Index	2002 \$
1984	45.0	67.27	72.7
1985	39.8	69.58	62.1
1986	29.0	71.40	44.1
1987	25.2	73.59	37.2
1988	24.0	76.28	34.2
1989	24.7	79.49	33.8
1990	38.6	82.93	50.6
1991	34.9	86.23	44.0
1992	32.8	88.60	40.2
1993	35.1	90.94	41.9
1994	32.4	93.11	37.8
1995	34.4	95.26	39.2
1996	46.1	97.05	51.6
1997	41.6	98.85	45.7
1998	28.8	100.00	31.3
1999	34.2	101.81	36.5
2000	76.7	103.85	80.2
2001		106.23	
2002		108.64	

Average =	46.07	Cents per gallon
Standard Deviation =	13.79	Cents per gallon
Average Plus Standard Deviation =	\$0.599	Dollars per gallon
Average Minus Standard Deviation =	\$0.323	Dollars per gallon

Mimimum =	\$0.313	(2002\$)
Maximum =	\$0.802	(2002\$)

**GROUP 2**  
**FUEL DISPLACEMENT OPTIONS**

## **Option 2A Fuel Cells (Analysis by Bill Blackburn)**

### **Description**

This option assumes that with considerable industry effort and government assistance, fuel cell vehicles realize a significant penetration in California's light-duty vehicle market by 2030.

### **Background**

Fuel cell vehicles (FCVs) hold the promise of high efficiency, zero or near-zero tail pipe emissions, and little or no evaporative emissions depending on the fuel used. FCVs have the potential for significantly better fuel economy than conventional internal combustion engine (ICE) vehicles. When operating on direct hydrogen, fuel cell vehicles produce no tail pipe emissions, only water and heat.

Like batteries, fuel cells provide electricity through an electrochemical reaction. However, fuel cells do not require electric recharging. Fuel cell vehicles and battery electric vehicles are sometimes called "electric drive vehicles" and utilize an electric motor rather than an internal combustion engine (ICE).

All fuel cells operate on hydrogen, which can be stored on-board the vehicle (direct) or produced on-board the vehicle from a hydrocarbon fuel with a reformer (indirect). Leading candidate fuels under consideration for onboard reforming include gasoline, methanol and ethanol.

Concerns continue over which fuel will be used as a source of hydrogen and who will pay for FCV infrastructure development. If an appropriate fueling infrastructure is not deployed in a timely manner or with convenient access, market development for FCVs may be severely constrained. In the case of direct hydrogen fuel cell vehicles, the cost of hydrogen station development can be several times higher than existing gasoline stations. If gasoline is to be utilized in FCVs, either the gasoline will need to be modified (i.e., refined to ultra-low sulfur levels), or gasoline reformers must improve to handle today's gasoline designed for internal combustion engines. In the long-term, the preferred fuel is hydrogen because of its superior environmental and potential energy benefits.

While ethanol could be used as a hydrogen source for FCVs, supply uncertainties for ethanol would have to be addressed given existing ethanol production plans. Staff is unaware of any automobile manufacturers pursuing an ethanol FCV option. Furthermore, prices for ethanol are expected to be higher on a cost per mile basis than other fuels considered here. If ethanol were to be utilized by FCVs it could potentially be used either in a neat feedstock (E100) or blended with gasoline (i.e., E10, E20, etc.) with petroleum savings corresponding to the blend level and efficiency gains – expected to be comparable to gasoline reformers.

Hydrogen is often seen as a dangerous fuel to store and handle, and appropriate fire and safety codes need to be developed.

### **Assumptions and Methodology**

Two fueling categories are presented for light-duty fuel cell vehicles:

- Non-petroleum – Vehicles that are fueled from a non-petroleum source, either hydrogen (direct), alcohol fuel (indirect, where hydrogen is produced from an onboard reformer) or a combination of the two fuels.
- Petroleum-based – Vehicles that are fueled with a petroleum-based hydrocarbon fuel (likely gasoline used with onboard reformer), which offer improved vehicle efficiency over conventional gasoline ICE vehicles, but of course displace much less petroleum.

Staff evaluated the cost of owning and operating fuel cell vehicles, based upon expected future performance levels and costs. Staff did not include any potential revenues from vehicle-to-grid connection of fuel cell vehicles.

### **Status of Fuel Cell Vehicles**

A few dozen light-duty FCVs are now being demonstrated around the world, notably in California under the auspices of the California Fuel Cell Partnership. Numerous automobile makers are devoting substantial resources toward the development of FCVs, with the hope that over the long-term the capital cost of various fuel cell technologies will become cost competitive with the gasoline ICE vehicle (as well as other competing technologies). However, this technology is pre-commercial and the likelihood of achieving substantial market penetration is uncertain. The timing, cost and durability of fuel cell technologies are all challenges that are being addressed by stakeholders.

The U.S. Department of Energy (DOE) spent \$36.6 million on fuel cell vehicle research and development (R&D) in fiscal year (FY) 2000, \$41.3 million in FY 2001, and requested \$41.9 million for FY 2002. Correspondingly, they requested \$8.7 million for electric drive vehicle (battery) R&D in FY 2000, \$9.0 million in FY 2001 and requested \$3.5 million for FY 2002.<sup>1</sup> Federal FCV R&D focused on lowering fuel cell stack and reformer component costs, improving fuel processor performance targets, integrating system components, and reducing costs for onboard hydrogen storage. Federal electric vehicle R&D focused on reducing battery costs, and is being reduced in scope to concentrate instead on fuel cell vehicles. The level of automobile manufacturer R&D devoted to FCVs is not known, but is believed to be tens of millions or higher annually.

While reducing the fuel cell stack cost and improving durability are probably the biggest challenges, several other technical design issues still must be resolved before fuel cell vehicles can become competitive with current vehicle technologies. These technical issues include fuel cell stack performance, balance of plant improvements (necessary supporting components), cold temperature operation, hydrogen storage technology, reformer development and others.<sup>2</sup>

**Table 2A-1. DOE Research and Development Goals for Fuel Cell Vehicles<sup>3</sup>**

	<b>Durability (hours)</b>	<b>Energy Efficiency at 25% Peak Power</b>	<b>Start Up Time To Full Power (minutes)</b>	<b>Power Density (watts/liter)</b>	<b>Specific Power (watts/kg)</b>
<b>Current Status (year 2000)</b>	1000	34	6.0	120	120
<b>2004 PNGV Goal</b>	5000	48	0.5	300	300

**Intermediate Market (2010-2020).** In the intermediate, or mid-term market, it is expected that FCVs will be commercially available and will experience substantial sales growth. Costs are assumed to be high compared to conventional gasoline vehicles, but falling as technology improves at a rapid pace. For example, Arthur D. Little estimates the incremental cost for FCVs during the 2010-2020 time period to be approximately \$9,000-11,000 per vehicle.<sup>4</sup> This higher cost would need to be offset with government incentives if this intermediate market grows.

Compared to current conventional gasoline ICE vehicles, intermediate market direct hydrogen FCVs that meet development goals could have 1.8 to 3.0 times higher equivalent fuel economy. Methanol steam reforming (SR) hybrid fuel cell vehicles could have 1.2 to 1.7 times higher fuel economy. Gasoline or ethanol hybrid auto-thermal reforming (ATR) fuel cell vehicles could have 1.1 to 1.6 times higher fuel economy. The following analyses employs nominal factors of 2.0, 1.5, and 1.4, for direct hydrogen, methanol steam reforming, and gasoline reforming, respectively. Results are shown per gallon of gasoline displaced. In the following tables, negative values represent a savings, and positive values represent a cost.

**Table 2A-2. Intermediate Market Hydrogen FCV**

FCV	Gasoline ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consume Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle- Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	6,300	-378	3,383	0.85	0.85
Low	Low	6,300	-177	4,931	1.12	1.12
High	High	12,300	-256	10,324	2.03	2.03
High	Low	12,300	-55	11,872	2.29	2.29

**Table 2A-3. Intermediate Market Methanol FCV**

FCV	Gasoline ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle- Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	7,000	-427	3,706	0.72	0.72
Low	Low	7,000	-226	5,254	0.98	0.98
High	High	13,000	-132	11,981	2.12	2.12
High	Low	13,000	68	13,529	2.39	2.39

**Table 2A-4. Intermediate Market Gasoline FCV**

FCV	Gasoline ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	8,200	-455	4,689	0.88	0.88
Low	Low	8,200	-254	6,237	1.14	1.14
High	High	14,200	-313	11,783	2.08	2.08
High	Low	14,200	-113	13,331	2.34	2.34

Negative values in the tables above represent savings; positive values represent costs. Since we assume continuation of existing fuel excise taxes, government would lose excise tax revenue because fewer gallons of fuel may be sold due to the increased efficiency. Government excise taxes lost are estimated at a present worth over the 10-year vehicle life of \$1,653 per vehicle year for hydrogen (no excise taxes are currently collected on hydrogen, same as mature market), \$549 per vehicle year for methanol and \$485 per vehicle year for gasoline. We also assume that government absorbs any net cost increases incurred by the FCV owner. Except for the incremental capital costs, results are shown in net present value 2002 dollars, over an assumed 10-year vehicle life, discounted at 5 percent (real).

**Mature Market (beyond 2020).** As stated above, fuel cell vehicles are at an early stage in their development, with major hurdles to overcome. Nevertheless, they show great potential and stakeholders are devoting large resources to overcome these hurdles. This process will take time. With current development progress, a small number of FCVs will be operating by 2010, comprising up to 4 percent of new vehicle sales by 2020 and reaching 10 percent or higher by 2030.

For light-duty FCVs to achieve a mature market and achieve the year 2020 sales volume, major technical and economic breakthroughs for fuel cells need to occur by about 2012. These breakthroughs would include improving fuel cell stack performance and reliability, improving reformer technology, significantly reducing costs for these systems, and improving hydrogen storage systems for direct hydrogen fuel cell vehicles. For example, to be competitive with gasoline ICE technology, the or cost of fuel cells per kilowatt (kW) will need to drop several times from the current amount to about \$45/kW (U.S. Department of Energy's goal).

Compared to current conventional gasoline ICE vehicles, mature market direct hydrogen FCVs that meet development goals could have 2.0 to 3.5 times higher equivalent fuel economy. Methanol steam reforming (SR) hybrid fuel cell vehicles could have 1.2 to 1.9 times higher fuel economy. Gasoline or ethanol hybrid auto-thermal reforming (ATR) fuel cell vehicles could have 1.2 to 1.7 times higher fuel economy. Rather than using the highest estimated efficiency improvement values, the following analyses employs nominal factors of 2.5, 1.7, and 1.5, for direct hydrogen, methanol steam reforming, and gasoline reforming, respectively.

The FCV lifecycle cost to vehicle owners are evaluated, assuming that cost and performance targets of R&D programs are met. Vehicle owners will probably still have to pay more for a FCV than a comparable gasoline ICE, even if R&D targets are met. However, expected fuel

savings and possible higher value features of FCVs (e.g., quieter operation and increased power availability) may justify a higher vehicle purchase price.

Negative values in the tables above represent savings; positive values represent costs. Since we assume continuation of existing fuel excise taxes, government would lose excise tax revenue because fewer gallons of fuel may be sold due to the increased efficiency. Government excise taxes lost are estimated at a present worth over the 10-year vehicle life of \$1,653 per vehicle year for hydrogen (no excise taxes are currently collected on hydrogen, same as intermediate market), \$682 per vehicle year for methanol and \$551 per vehicle year for gasoline. We also assume that government absorbs any net cost increases incurred by the FCV owner. Results are shown for a mature technology, with various fuel supply alternatives. Except for the incremental capital costs, results are shown in net present value 2002 dollars, over an assumed 10-year vehicle life, discounted at 5 percent (real).

At the incremental vehicle and fuel costs assumed, when costs are low for the FCV and high for the gasoline ICE, for all three types of fuel supply, the consumer saves money over the lifetime of the vehicle while the government loses excise taxes. When costs vary together and are either high or low at the same time, fuel cell vehicles cost more for all three fuel supply types. Finally, when FCV costs are high and gasoline ICE costs are low (as is the current situation), FCVs are much more expensive than gasoline ICEs. Results are shown per gallon of gasoline displaced. In the following tables, negative values represent a savings, and positive values represent a cost.

**Table 2A-5. Mature Market Hydrogen FCV**

FCV	Gasoline ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	1,000	-488	-2,765	0.28	-0.19
Low	Low	1,000	-287	-1,217	0.28	0.07
High	High	3,600	-391	580	0.38	0.38
High	Low	3,600	-191	2,128	0.64	0.64

**Table 2A-6. Mature Market Methanol FCV**

FCV	Gasoline ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	1000	-501	-2,870	0.12	-0.37
Low	Low	1000	-301	-1,322	0.12	-0.11
High	High	3,600	-242	1,730	0.41	0.41
High	Low	3,600	-42	3,278	0.67	0.67

**Table 2A-7. Mature Market Gasoline FCV**

FCV	Gasoline ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	1,500	-489	-2,279	0.09	-0.29
Low	Low	1,500	-289	-731	0.09	-0.03
High	High	4,500	-356	1,753	0.39	0.39
High	Low	4,500	-155	3,301	0.65	0.65

**Gasoline Displacement.** In non-petroleum FCVs such as hydrogen and methanol, no gasoline is consumed in the FCV, thereby displacing 100 percent of the amount of gasoline that the displaced vehicle would have used. For petroleum-based FCVs, it is assumed that a mature gasoline-fueled FCV achieves 1.5 times higher fuel economy than a comparable gasoline ICE vehicle.

**Table 2A-8. Hydrogen and Methanol FCV Gasoline Displacement**

	Annual Petroleum Reduction		
	2010	2020	2030
Annual Reduction in Gasoline Consumption (million gallons)	N/A	750	2,160
Reduction From Base Case Demand (Percent)	N/A	4	10

**Table 2A-9. Gasoline FCV Gasoline Displacement**

	Annual Petroleum Reduction		
	2010	2020	2030
Annual Reduction in Gasoline Consumption (million gallons)	N/A	250	710
Reduction From Base Case Demand (Percent)	N/A	1	3

### Key Drivers and Uncertainties

Highlighted below are many of the major uncertainties with FCVs and the key drivers that will ultimately determine the market success of this emerging technology.

- Costs of fuel cell system (success in meeting capital cost R&D targets) and available incentives.
- The willingness of energy industry or government to invest and initially share the cost of fueling infrastructure development, particularly important for hydrogen.
- Costs of fuel for FCVs, especially hydrogen.
- System efficiency of fuel cell vehicles (success in meeting efficiency R&D targets).
- Choice of fuel or fuels for FCVs. Several candidates are under consideration and this issue should be resolved as fuel cell stack technology advances. There is a general consensus that hydrogen is the preferred fuel in the long term, pending resolution of supply and storage issues.

---

<sup>1</sup> U.S. Department of Energy, FY 2002 Congressional Budget Request, Energy Efficiency and Renewable Energy, Energy Conservation.

<sup>2</sup> Arthur D. Little, *Projected Automotive Fuel Cell Use in California*, October 2001.

<sup>3</sup> U.S. Department of Energy, *2000 Annual Progress Report, Transportation Fuel Cell Power Systems*. Partnership for New Generation of Vehicles 2004 Goal.

<sup>4</sup> Arthur D. Little, *Guidance for Transportation Technologies: Fuel Choice for Fuel Cell Vehicles*, December 2001 (p. 81). BKI, *Bringing Fuel Cell Vehicles to Market: Scenarios and Challenges with Fuel Alternatives*, October 2001.

Option 2A--Hydrogen FCVs, Intermediate Market

INPUTS

Fleet Information	Units	Hydrogen FCV	Units	Gasoline
Number of Vehicles	Vehicles	630	Vehicles	630
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/GGE	42.0	Miles/Gal	21.2
Fuel Consumption	GGE/Year	187,500	Gal/Year	371,462
Daily Consumption	GGE/weekday	601	Gal/weekday	1,191

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Hydrogen FCV		Gasoline ICE	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$12,300	\$6,300	\$0	\$0
Total Incremental Vehicle Cost	\$	\$7,749,000	\$3,969,000	\$0	\$0

Fuel Costs	Units	Hydrogen		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$2.73	\$2.32	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$511,102	\$434,330	\$672,347	\$546,050

OUTPUTS

Hydrogen FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (H2-Gasoline)	Incremental Annual Fuel Cost (H2-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$3,969,000	-\$238,017	\$2,131,095	\$1,041,205	\$3,172,300	\$0.854	\$0.854
High	Low	\$7,749,000	-\$34,948	\$7,479,141	\$1,041,205	\$8,520,346	\$2.294	\$2.294
Low	Low	\$3,969,000	-\$111,720	\$3,106,329	\$1,041,205	\$4,147,534	\$1.117	\$1.117
High	High	\$7,749,000	-\$161,245	\$6,503,907	\$1,041,205	\$7,545,112	\$2.031	\$2.031

Hydrogen FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (H2-Gasoline)	Incremental Annual Fuel Cost (H2-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$6,300	-\$378	\$3,383	\$1,653	\$5,035	\$5,035
High	Low	\$12,300	-\$55	\$11,872	\$1,653	\$13,524	\$13,524
Low	Low	\$6,300	-\$177	\$4,931	\$1,653	\$6,583	\$6,583
High	High	\$12,300	-\$256	\$10,324	\$1,653	\$11,976	\$11,976

("-" represents savings to user; no government cost)

## Option 2A--Hydrogen FCVs, Intermediate Market

### INPUTS

Unit

#### Fleet Information

Number of Vehicles		630
Fuel Consumption	<b>Gallons/Year</b>	187,500
Daily Consumption	<b>Gallons/weekday</b>	601

#### Station Owner Information

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

#### Capital Costs

Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$700,000
Station Upgrade Expenses (total)	<b>\$</b>	\$700,000

(Mature hydrogen station, using natural gas reforming)

#### Other Costs

Revenue From Retail Mark-Up	<b>\$/year</b>	\$28,125
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00
Gulf Coast to CA Annual Import Cost	<b>\$/year</b>	\$0

(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low Hydrogen Wholesale Cost	\$1.50	\$93,715	\$309,375	\$403,090	\$2.15	\$2.32
High Hydrogen Wholesale Cost	\$1.88	\$93,715	\$380,625	\$474,340	\$2.53	\$2.73

(Sales Tax only)

(Sales Tax only)

	<b>Hydrogen</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =		112,000	126,000
CA Taxes =		\$0.18	\$0.24
Fed Taxes =		\$0.18	\$0.18
Total Exise Taxes =		\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

Option 2A--Methanol FCVs, Intermediate Market

INPUTS

Fleet Information	Units	Methanol	Units	Gasoline
Number of Vehicles	Vehicles	490	Vehicles	490
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gal	16.0	Miles/Gal	21.2
Fuel Consumption	Gal/Year	382,813	Gal/Year	288,915
Daily Consumption	Gal/weekday	1,227	Gal/weekday	926

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Methanol FCV		Gasoline ICE	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$13,000	\$7,000	\$0	\$0
Total Incremental Vehicle Cost	\$	\$6,370,000	\$3,430,000	\$0	\$0

Fuel Costs	Units	Methanol		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.20	\$0.82	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$458,257	\$313,889	\$522,936	\$424,705

OUTPUTS

Methanol FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (MEOH-Gasoline)	Incremental Annual Fuel Cost (MEOH-Gasoline)	Present Value Consumer Costs (" " Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$3,430,000	-\$209,048	\$1,815,788	\$268,882	\$2,084,671	\$0.722	\$0.722
High	Low	\$6,370,000	\$33,552	\$6,629,076	\$268,882	\$6,897,958	\$2.388	\$2.388
Low	Low	\$3,430,000	-\$110,817	\$2,574,303	\$268,882	\$2,843,185	\$0.984	\$0.984
High	High	\$6,370,000	-\$64,680	\$5,870,561	\$268,882	\$6,139,443	\$2.125	\$2.125

Methanol FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (MEOH-Gasoline)	Incremental Annual Fuel Cost (MEOH-Gasoline)	Present Value Consumer Cost Net Present Value (" " Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$7,000	-\$427	\$3,706	\$549	\$4,254	\$4,254
High	Low	\$13,000	\$68	\$13,529	\$549	\$14,077	\$14,077
Low	Low	\$7,000	-\$226	\$5,254	\$549	\$5,802	\$5,802
High	High	\$13,000	-\$132	\$11,981	\$549	\$12,529	\$12,529

("-" represents savings to user; no government cost)

## Option 2A--Methanol FCVs, Intermediate Market

### INPUTS

#### Unit

#### Fleet Information

Number of Vehicles		490
Fuel Consumption	<b>Gallons/Year</b>	382,813
Daily Consumption	<b>Gallons/weekday</b>	1,227

#### Station Owner Information

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

#### Capital Costs

Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$80,000
Station Upgrade Expenses (total)	<b>\$</b>	\$80,000

(Assumes 490 vehicles per station)

#### Other Costs

Revenue From Retail Mark-Up	<b>\$/year</b>	\$57,422
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00
Gulf Coast to CA Annual Import Cost	<b>\$/year</b>	\$0

(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low MEOH Wholesale Cost	\$0.40	\$10,710	\$210,547	\$221,257	\$0.58	\$0.82
High MEOH Wholesale Cost	\$0.75	\$10,710	\$344,531	\$355,242	\$0.93	\$1.20

	<b>Methanol</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =		112,000	126,000
CA Taxes =	\$0.090	\$0.18	\$0.24
Fed Taxes =	\$0.093	\$0.18	\$0.18
Total Exise Taxes =	\$0.183	\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

Option 2A--Gasoline FCVs, Intermediate Market

INPUTS

Fleet Information	Units	Gasoline FCV	Units	Gasoline ICE
Number of Vehicles	Vehicles	490	Vehicles	490
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gal	30.0	Miles/Gal	21.2
Fuel Consumption	Gal/Year	204,167	Gal/Year	288,915
Daily Consumption	Gal/weekday	654	Gal/weekday	926

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Gasoline FCV		Gasoline ICE	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$14,200	\$8,200	\$0	\$0
Total Incremental Vehicle Cost	\$	\$6,958,000	\$4,018,000	\$0	\$0

Fuel Costs	Units	Gasoline		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.81	\$1.47	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$369,542	\$300,125	\$522,936	\$424,705

OUTPUTS

Gasoline FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (GFCV-Gasoline)	Incremental Annual Fuel Cost (GFCV-Gasoline)	Present Value Consumer Costs (" " Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$4,018,000	-\$222,811	\$2,297,510	\$237,549	\$2,535,059	\$0.877	\$0.877
High	Low	\$6,958,000	-\$55,164	\$6,532,042	\$237,549	\$6,769,591	\$2.343	\$2.343
Low	Low	\$4,018,000	-\$124,580	\$3,056,025	\$237,549	\$3,293,574	\$1.140	\$1.140
High	High	\$6,958,000	-\$153,395	\$5,773,527	\$237,549	\$6,011,076	\$2.081	\$2.081

Gasoline FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (GFCV-Gasoline)	Incremental Annual Fuel Cost (GFCV-Gasoline)	Present Value Consumer Cost Net Present Value (" " Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$8,200	-\$455	\$4,689	\$485	\$5,174	\$5,174
High	Low	\$14,200	-\$113	\$13,331	\$485	\$13,815	\$13,815
Low	Low	\$8,200	-\$254	\$6,237	\$485	\$6,722	\$6,722
High	High	\$14,200	-\$313	\$11,783	\$485	\$12,268	\$12,268

("-" represents savings to user; no government cost)

Option 2A--Hydrogen FCVs, Mature Market

INPUTS

Fleet Information	Units	Hydrogen FCV	Units	Gasoline
Number of Vehicles	Vehicles	630	Vehicles	630
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/GGE	53.0	Miles/Gal	21.2
Fuel Consumption	GGE/Year	148,585	Gal/Year	371,462
Daily Consumption	GGE/weekday	476	Gal/weekday	1,191

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Hydrogen FCV		Gasoline ICE	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$3,600	\$1,000	\$0	\$0
Total Incremental Vehicle Cost	\$	\$2,268,000	\$630,000	\$0	\$0

Fuel Costs	Units	Hydrogen		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$2.87	\$2.46	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$425,982	\$365,143	\$672,347	\$546,050

OUTPUTS

Hydrogen FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (H2-Gasoline)	Incremental Annual Fuel Cost (H2-Gasoline)	Present Value Consumer Costs ("=" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$630,000	-\$307,203	-\$1,742,142	\$1,041,205	\$1,041,205	-\$0.189	\$0.280
High	Low	\$2,268,000	-\$120,068	\$1,340,867	\$1,041,205	\$2,382,072	\$0.641	\$0.641
Low	Low	\$630,000	-\$180,906	-\$766,909	\$1,041,205	\$1,041,205	\$0.074	\$0.280
High	High	\$2,268,000	-\$246,365	\$365,634	\$1,041,205	\$1,406,839	\$0.379	\$0.379

Hydrogen FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (H2-Gasoline)	Incremental Annual Fuel Cost (H2-Gasoline)	Present Value Consumer Cost Net Present Value ("=" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$1,000	-\$488	-\$2,765	\$1,653	\$1,653	-\$1,113
High	Low	\$3,600	-\$191	\$2,128	\$1,653	\$3,781	\$3,781
Low	Low	\$1,000	-\$287	-\$1,217	\$1,653	\$1,653	\$435
High	High	\$3,600	-\$391	\$580	\$1,653	\$2,233	\$2,233

("=" represents savings to user; no government cost)

## Option 2A--Hydrogen FCVs, Mature Market

### INPUTS

#### Unit

#### Fleet Information

Number of Vehicles		630
Fuel Consumption	<b>Gallons/Year</b>	148,585
Daily Consumption	<b>Gallons/weekday</b>	476

#### Station Owner Information

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

#### Capital Costs

Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$700,000
Station Upgrade Expenses (total)	<b>\$</b>	\$700,000

(Mature hydrogen station, using natural gas reforming)

#### Other Costs

Revenue From Retail Mark-Up	<b>\$/year</b>	\$22,288
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00
Gulf Coast to CA Annual Import Cost	<b>\$/year</b>	\$0

(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low Hydrogen Wholesale Cost	\$1.50	\$93,715	\$245,165	\$338,880	\$2.28	\$2.46
High Hydrogen Wholesale Cost	\$1.88	\$93,715	\$301,627	\$395,343	\$2.66	\$2.87

(Sales Tax only)

(Sales Tax only)

	<b>Hydrogen</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =		112,000	126,000
CA Taxes =		\$0.18	\$0.24
Fed Taxes =		\$0.18	\$0.18
Total Exise Taxes =		\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

Option 2A--Methanol FCVs, Mature Market

INPUTS

Fleet Information	Units	Methanol	Units	Gasoline
Number of Vehicles	Vehicles	490	Vehicles	490
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gal	18.2	Miles/Gal	21.2
Fuel Consumption	Gal/Year	336,538	Gal/Year	288,915
Daily Consumption	Gal/weekday	1,079	Gal/weekday	926

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Methanol FCV		Gasoline ICE	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$3,600	\$1,000	\$0	\$0
Total Incremental Vehicle Cost	\$	\$1,764,000	\$490,000	\$0	\$0

Fuel Costs	Units	Methanol		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.20	\$0.82	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$404,258	\$277,341	\$522,936	\$424,705

OUTPUTS

Methanol FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (MEOH-Gasoline)	Incremental Annual Fuel Cost (MEOH-Gasoline)	Present Value Consumer Costs (" " Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$490,000	-\$245,595	-\$1,406,422	\$334,271	\$334,271	-\$0.371	\$0.116
High	Low	\$1,764,000	-\$20,447	\$1,606,112	\$334,271	\$1,940,384	\$0.672	\$0.672
Low	Low	\$490,000	-\$147,364	-\$647,908	\$334,271	\$334,271	-\$0.109	\$0.116
High	High	\$1,764,000	-\$118,678	\$847,598	\$334,271	\$1,181,869	\$0.409	\$0.409

Methanol FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (MEOH-Gasoline)	Incremental Annual Fuel Cost (MEOH-Gasoline)	Present Value Consumer Cost Net Present Value (" " Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$1,000	-\$501	-\$2,870	\$682	\$682	-\$2,188
High	Low	\$3,600	-\$42	\$3,278	\$682	\$3,960	\$3,960
Low	Low	\$1,000	-\$301	-\$1,322	\$682	\$682	-\$640
High	High	\$3,600	-\$242	\$1,730	\$682	\$2,412	\$2,412

("-" represents savings to user; no government cost)

## Option 2A--Methanol FCVs, Mature Market

### INPUTS

Unit

#### Fleet Information

Number of Vehicles		490
Fuel Consumption	<b>Gallons/Year</b>	336,538
Daily Consumption	<b>Gallons/weekday</b>	1,079

#### Station Owner Information

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

#### Capital Costs

Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$80,000
Station Upgrade Expenses (total)	<b>\$</b>	\$80,000

(Assumes 490 vehicles per station)

#### Other Costs

Revenue From Retail Mark-Up	<b>\$/year</b>	\$50,481
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00
Gulf Coast to CA Annual Import Cost	<b>\$/year</b>	\$0

(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low MEOH Wholesale Cost	\$0.40	\$10,710	\$185,096	\$195,806	\$0.58	\$0.82
High MEOH Wholesale Cost	\$0.75	\$10,710	\$302,885	\$313,595	\$0.93	\$1.20

	<b>Methanol</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =		112,000	126,000
CA Taxes =	\$0.090	\$0.18	\$0.24
Fed Taxes =	\$0.093	\$0.18	\$0.18
Total Exise Taxes =	\$0.183	\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

Option 2A--Gasoline FCVs, Mature Market

INPUTS

Fleet Information	Units	Gasoline FCV	Units	Gasoline ICE
Number of Vehicles	Vehicles	490	Vehicles	490
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gal	31.8	Miles/Gal	21.2
Fuel Consumption	Gal/Year	192,610	Gal/Year	288,915
Daily Consumption	Gal/weekday	617	Gal/weekday	926

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Gasoline FCV		Gasoline ICE	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$4,500	\$1,500	\$0	\$0
Total Incremental Vehicle Cost	\$	\$2,205,000	\$735,000	\$0	\$0

Fuel Costs	Units	Gasoline		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.81	\$1.47	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$348,624	\$283,137	\$522,936	\$424,705

OUTPUTS

Gasoline FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (GFCV-Gasoline)	Incremental Annual Fuel Cost (GFCV-Gasoline)	Present Value Consumer Costs (" " Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$735,000	-\$239,800	-\$1,116,668	\$269,942	\$269,942	-\$0.293	\$0.093
High	Low	\$2,205,000	-\$76,081	\$1,617,523	\$269,942	\$1,887,465	\$0.653	\$0.653
Low	Low	\$735,000	-\$141,568	-\$358,154	\$269,942	\$269,942	-\$0.031	\$0.093
High	High	\$2,205,000	-\$174,312	\$859,008	\$269,942	\$1,128,950	\$0.391	\$0.391

Gasoline FCV	Gasoline ICE	Incremental Annual Vehicle Capital Cost (GFCV-Gasoline)	Incremental Annual Fuel Cost (GFCV-Gasoline)	Present Value Consumer Cost Net Present Value (" " Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$1,500	-\$489	-\$2,279	\$551	\$551	-\$1,728
High	Low	\$4,500	-\$155	\$3,301	\$551	\$3,852	\$3,852
Low	Low	\$1,500	-\$289	-\$731	\$551	\$551	-\$180
High	High	\$4,500	-\$356	\$1,753	\$551	\$2,304	\$2,304

("-" represents savings to user; no government cost)

## **Option 2B**

### **Electric Battery Technologies**

**(Analysis by David Ashuckian, Gerry Bemis, and Dan Fong)**

#### **Description**

This option would provide additional funding to reduce the cost of battery-powered electric drive vehicles, and provide additional incentives equal to the incremental cost of a battery electric vehicles to reach market penetration levels which exceed the Air Resources Board's Zero Emission Vehicle (ZEV) mandate.

#### **Background**

In 1990, the California Air Resources Board adopted low-emission vehicle standards that included a requirement that automobile manufacturers offer a minimum percentage of zero-emission vehicles for sale. Although the actual minimum percentage has been reduced over the past 12 years, there is still a requirement that manufacturers produce and offer for sale, a limited number of zero-emission vehicles beginning in model year 2003. The commercialization status of zero-emission vehicle technology limits automaker options to battery powered electric vehicles.

The development of more cost-effective battery electric drive technologies can potentially improve the competitiveness of battery-electric vehicles, fuel cell vehicles, and gasoline- electric hybrid vehicles. With additional research and development (R&D), technology advancements could increase the range and utility of these vehicles resulting in an increased number of vehicles that could be introduced in California beyond the minimum number required by the ZEV regulation.

However, these technology improvements may only have a marginal impact on gasoline consumption since battery electric vehicles are already included in the base case forecast at levels required by California's Low-Emission Vehicle Standards.

Neighborhood electric vehicles are excluded from this option. Preliminary results from demonstrations with these vehicles have revealed that they consume relatively few gallons of gasoline per year, and therefore are not be expected to displace much petroleum. However, staff has included city or urban electric vehicles in this evaluation.

#### **Assumptions and Methodology**

We assume that the ZEV mandate is met, and the base case demand level incorporates the effect of the ZEV mandate in reducing gasoline demand. To increase market penetration, lower cost batteries would be needed and there needs to be additional vehicle purchase incentives to offset the additional capital cost. This would require expanded R&D. We discuss the status of battery electric vehicles, including R&D trends, then evaluate life cycle costs for them, assuming they reach a mature market condition. Finally, we assume the CEC's forecasted year 2012 residential

electricity rates and home battery recharging. The high electricity price estimate is the highest retail rate for the three investor-owned electric utilities plus LADWP and SMUD. The lower price is the lowest of the forecast in year 2012 for the same utilities, assuming an off-peak discount of 40 percent applies.

One strategy for improving the cost-effectiveness of electric drive vehicles, including electric battery vehicles, is to use them for Ancillary Services while connected to the electric grid. See Option 2C for a discussion this additional potential source of revenue. The effect of this additional revenue, if realized, would improve the cost-effectiveness of electric drive vehicles.

### **Status of Battery Electric Vehicles**

In efforts by automobile manufacturers to meet the ARB's ZEV program requirements, a very limited number of electric drive vehicles have been offered for lease or sale. The battery electric vehicles being sold today have an incremental battery cost premium of \$30,000 relative to similar gasoline powered internal combustion engine (ICE) vehicles. City electric vehicles available today have an incremental cost of \$20,000. However, the range of these vehicle classes and the durability of their batteries have not approached the performance of similar gasoline ICE vehicles.

This analysis assumes that further research and development will eventually reduce the cost of batteries into the range projected by the Air Resources Board's Battery Technology Advisory Panel. This independent panel stated that nickel-metal hydride batteries show the greatest potential for reaching technical maturity and cost targets. The panel projected the mature technology cost to range from \$225 to \$250 per kWh in large production quantities of 100,000 battery packs per year.<sup>1</sup> This leads to an incremental price of \$8,000 to \$10,000 per vehicle including an additional cost of \$600 to \$1,200 per vehicle for electric and thermal management systems and \$1,000 for recharging infrastructure. Recent information presented to Air Resources Board staff<sup>2</sup> by one battery manufacturer estimated that Lithium-Metal-Polymer battery costs could reach a level of \$200/kWh in high production levels. This would result in an incremental cost of approximately \$7,600. For city vehicles, staff assumed that the cost of batteries for city EV would be approximately one-third the cost of full size battery modules with an equivalent fuel economy of 45 miles per gallon compared to the average vehicle fuel economy.<sup>3</sup>

In their 1995 report,<sup>4</sup> The Advanced Battery Panel estimated that in order to reach their projected cost targets, investments in R&D and in a battery plant capable of producing batteries in volumes needed to lower unit cost would be between \$180 million and \$400 million over 9 years. Current research and development aimed at reducing battery costs is low and declining compared to recent historical levels. The U.S. Department of Energy (DOE)<sup>5</sup> spent \$8.7 million for electric drive vehicle R&D in FY 2000, \$9.0 million in FY 2001 and requested only \$3.5 million for FY 2002. Federal electric vehicle R&D during that time focused on attempts to reduce battery costs. Presently, the scope of their R&D funding is being reduced in scope to concentrate instead on fuel cell vehicles (see Option 2A).

## Results

**Intermediate Market.** A mature market for battery electric vehicles is assumed to develop by 2030 and the gasoline ICE vehicle population is reduced by 10 percent from the base case, as discussed below. To reach that level of market penetration by 2030, the EV population is assumed to transition through an intermediate market, reaching 4 percent of the light-duty vehicle population by 2020. Capital costs for this market condition were derived from the Air Resources Board's Battery Technology Advisory Panel for intermediate production levels of 20,000 per year.<sup>6</sup> Home recharging infrastructure costs of \$1,000 is included in the incremental vehicle capital cost. Battery replacement cost is not included (assumes batteries last life of vehicle).

**Table 2B-1. Intermediate Market Electric Light-Duty Vehicles**

Battery Electric Vehicles	Gasoline ICE Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	10,500	-680	5,250	1.17	1.17
Low	Low	10,500	-479	6,798	1.43	1.43
High	High	14,000	-222	12,284	2.36	2.36
High	Low	14,000	-22	13,832	2.63	2.63

Note that these costs are compared to a gasoline vehicle and the "gallon" unit is a displaced gallon of gasoline. Negative values are savings and positive values are additional costs compared to gasoline. In the intermediate market, government loses \$1,653 per year in present worth excise taxes.

**Mature Market.** As stated above, battery-electric vehicle target costs and performance levels have been difficult to achieve, although some gains have occurred over the past 10 years. The capital cost, range and operating cost (i.e., including battery life and replacement cost) of a full-function battery-electric vehicle (EV) are considerably less attractive than a gasoline powered ICE vehicle. Nevertheless, there are potentially significant environmental benefits and strong advocates for their use. If a mature market develops (beyond the mandated level of market penetration), it will occur because R&D is expanded and materials costs are reduced. This process will take time. If the cost and performance targets used in the mature market condition are met, a small number of full-function EVs could be operating in California in 2010, growing to about 4 percent of California's light-duty fleet population by 2020 and reaching 10 percent by 2030.

By assuming that R&D cost and performance targets are met discussed above, and a cost of \$1,000 per vehicle is added for home recharging equipment and installation, a battery EV's lifecycle cost to vehicle owners and government is evaluated. For comparison purposes, the lifecycle costs assuming current prices and a similar home recharging cost is also evaluated. Battery replacement cost is assumed to be zero (assumes batteries last life of vehicle).

A range of 6.2 to 13.5 cents per kWh for the cost of recharging the battery was also assumed. This is the range of residential retail prices estimated by the Energy Commission<sup>7</sup> for Pacific Gas and Electric, Southern California Edison, San Diego Gas and Electric, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District territories. The lower number includes a 40 percent discount for off-peak charging. These rates are the same as the intermediate market case due to the uncertain timing of both forms of market and the lack of significant variability in the later years of the forecast.

At the incremental vehicle and fuel costs at current levels and at levels assumed above, the battery-electric vehicle costs more to own and operate than the gasoline ICE vehicle. For the increased market penetration levels to be realized, it is assumed that government absorbs any net cost increases incurred by the battery-electric vehicle owner over a comparable conventional gasoline vehicle. The Government Costs are equal to the Life Cycle Overall Cost because it is assumed that government pays for all cost increases. Results are shown in net present value 2002 dollars, over an assumed 10-year vehicle life, discounted at 5 percent real except for incremental capital costs, which are already in net present value terms.

**Table 2B-2. Mature Market Electric Light-Duty Vehicles**

Battery Electric Vehicles	Gasoline ICE Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	7,600	-680	2,350	0.68	0.68
Low	Low	7,600	-479	3,898	0.94	0.94
High	High	10,000	-223	8,274	1.68	1.68
High	Low	10,000	-23	9,822	1.95	1.95

Note that these costs are compared to a gasoline vehicle and the “gallon” unit is a displaced gallon of gasoline. Negative values are savings and positive values are additional costs compared to gasoline. In the mature market, government loses \$1,653 per year in present worth excise taxes.

Staff also evaluated the potential cost-benefits of city EVs compared to full size EVs. In this analysis, staff assumed battery costs ranging from \$2,333 to \$3,400 (plus \$1,000 for at-home recharging), with a 50 mile range, compared to a conventional vehicle that had a 45 mile per gallon fuel economy. Using the Society of Automotive Engineers utility factors to determine the annual number of vehicle miles traveled that a limited range vehicle would displace, staff calculated the net cost per vehicle to range between \$3,277 and \$6,470 including \$1,000 in home recharging infrastructure (see Option 2C). The present value of cost per gallon of gasoline displaced for the city electric vehicle ranges between \$2.36 to \$4.66. These values are higher than the values calculated for the full size electric vehicle and therefore, were not included in the mature market table.

**Gasoline Displacement.** A mature market for battery electric vehicles is assumed to develop by 2030 and the gasoline ICE vehicle population is reduced by 10 percent from the base case. To

reach that level of market penetration by 2030, the EV population is assumed to reach 4 percent of the light-duty vehicle population by 2020.

**Table 2B-3. Mature Market Gasoline Displacement**

	Annual Petroleum Reduction		
	2010	2020	2030
Annual Reduction in Gasoline Consumption (million gallons)	N/A	750	2,160
Reduction From Base Case Demand (Percent)	N/A	4	10

### **Key Drivers and Uncertainties**

1. There is uncertainty that additional research funding can reduce the cost of manufacturing advanced batteries for electric vehicles to the level assumed in this analysis.
2. There is uncertainty in consumer interest in purchasing a battery electric vehicle that would still have less utility compared to a gasoline powered vehicle.
3. There is uncertainty on the amount of incentives required to influence consumers to acquire an electric vehicle.
4. There is uncertainty in manufacturer interest in producing additional battery electric vehicles for sale.
5. There is significant uncertainty in the battery replacement cost. This analysis assumes batteries will last the full 10-year life of the vehicle.

---

<sup>1</sup> Advanced Batteries for Electric Vehicles: An Assessment of Performance, Cost, and Availability, 2000. M. Anderman, F.R. Kalhammer, D. MacArther.

<sup>2</sup> Presentation by Avestor to Tom Cackette, February 2002

<sup>3</sup> Conversation with Chuck Shulock, March 13, 2002 on City EV batteries in a mature market. ARB staff estimated cost to be 1/3 compared to full size EVs or about \$3,400.

<sup>4</sup> Performance and Availability of Batteries for Electric Vehicles: a Report of the Battery Technical Advisory Panel. 1995. F.R. Kalhammer, A. Kozawa, C.B. Moyer, B.B. Owens.

<sup>5</sup> Department of Energy, FY 2002 Congressional Budget Request, Energy Efficiency and Renewable Energy & Energy Conservation.

<sup>6</sup> Advanced Batteries for Electric Vehicles: An Assessment of Performance, Cost, and Availability, 2000. M. Anderman, F.R. Kalhammer, D. MacArther.

<sup>7</sup> 2002—2012 Electricity Outlook Report, P700-01-004F, February 2002, Table III-2-4, adjusted to 2002 dollars.

# Option 2B--Battery Electric Light-Duty Vehicles (Intermediate Market)

## INPUTS

Fleet Information	Units	Electric Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1	Vehicles	1
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/kWh	2.0	Miles/Gallon	21.2
Fuel Consumption	kWh/Year	6,250	Gallons/Year	590
Daily Consumption	kWh/weekday	20	Gallons/weekday	2

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Electric Vehicle		Gasoline ICE Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$14,000	\$10,500	\$0	\$0
Total Incremental Vehicle Cost	\$	\$14,000	\$10,500	\$0	\$0

(Includes \$1,000 for infrastructure)

Fuel Costs	Units	Electricity		Gasoline	
		Higher Price Estimate	Lower Price Estimate	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/kWh & \$/gal	\$0.135	\$0.062	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$845	\$387	\$1,067	\$867

(Note: Lower price is discounted by 40%)

## OUTPUTS

Electric Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (EV-Gasoline)	Incremental Annual Fuel Cost (EV-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$10,500	-\$680	\$5,250	\$1,653	\$6,903	\$1.171	\$1.171
High	Low	\$14,000	-\$22	\$13,832	\$1,653	\$15,485	\$2.626	\$2.626
Low	Low	\$10,500	-\$479	\$6,798	\$1,653	\$8,451	\$1.433	\$1.433
High	High	\$14,000	-\$222	\$12,284	\$1,653	\$13,937	\$2.364	\$2.364

(Note: Assumes all "+" Consumer Costs paid by Government)

Electric Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (EV-Gasoline)	Incremental Annual Fuel Cost (EV-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$10,500	-\$680	\$5,250	\$1,653	\$6,903	\$6,903
High	Low	\$14,000	-\$22	\$13,832	\$1,653	\$15,485	\$15,485
Low	Low	\$10,500	-\$479	\$6,798	\$1,653	\$8,451	\$8,451
High	High	\$14,000	-\$222	\$12,284	\$1,653	\$13,937	\$13,937

("-" represents savings to user; no government cost)

## Option 2B--Battery Electric Light-Duty Vehicles (Intermediate Market)

### INPUTS

Unit

#### Fleet Information

Number of Vehicles		1
Fuel Consumption	kWh/Year	6,250
Daily Consumption	kWh/weekday	20

#### Station Owner Information

ROI	%	12%
Investment Life	Year	20

#### Capital Costs

Number of Stations	each	0
Station Upgrade cost (each)	Dollars	\$0
Station Upgrade Expenses (total)	\$	\$0

#### Other Costs

Station Gasoline Gross Margin	\$/year	\$0	(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	\$/kWh	\$0.00	
Gulf Coast to CA ADSL Annual Import Cost	\$/year	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	Fuel Cost to Station Owner	Target Return on Capital	Annual Fuel Cost	Target Revenue from Fuel Sales	Target Fuel Price without Taxes	Fuel Price with Taxes
	\$/kWh	\$/year	\$/year	\$	\$/kWh	\$/kWh
Low Consumer Cost	\$0.062	\$0	\$388	\$388	\$0.06	\$0.062
High Consumer Cost	\$0.135	\$0	\$844	\$844	\$0.14	\$0.135

	Electricity	Gasoline	Diesel
LHV Energy Content =	3,412	112,000	126,000
CA Taxes =		\$0.18	\$0.24
Fed Taxes =		\$0.18	\$0.18
Total Exise Taxes =		\$0.36	\$0.42
Sales Taxes =	0.00%	7.75%	7.75%

# Option 2B--Battery Electric Light-Duty Vehicles (Mature Market)

## INPUTS

Fleet Information	Units	Electric Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1	Vehicles	1
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/kWh	2.0	Miles/Gallon	21.2
Fuel Consumption	kWh/Year	6,250	Gallons/Year	590
Daily Consumption	kWh/weekday	20	Gallons/weekday	2

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Electric Vehicle		Gasoline ICE Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$10,000	\$7,600	\$0	\$0
Total Incremental Vehicle Cost	\$	\$10,000	\$7,600	\$0	\$0

(Includes \$1,000 for infrastructure)

Fuel Costs	Units	Electricity		Gasoline	
		Higher Price Estimate	Lower Price Estimate	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/kWh & \$/gal	\$0.135	\$0.062	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$844	\$387	\$1,067	\$867

(Note: Lower Price Estimate is discounted by 40%)

## OUTPUTS

Electric Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (EV-Gasoline)	Incremental Annual Fuel Cost (EV-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$7,600	-\$680	\$2,350	\$1,653	\$4,003	\$0.679	\$0.68
High	Low	\$10,000	-\$23	\$9,822	\$1,653	\$11,475	\$1.946	\$1.95
Low	Low	\$7,600	-\$479	\$3,898	\$1,653	\$5,551	\$0.941	\$0.94
High	High	\$10,000	-\$223	\$8,274	\$1,653	\$9,927	\$1.684	\$1.68

(Note: Assumes all "+" Consumer Costs paid by Government)

Electric Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (EV-Gasoline)	Incremental Annual Fuel Cost (EV-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$7,600	-\$680	\$2,350	\$1,653	\$4,003	\$4,003
High	Low	\$10,000	-\$23	\$9,822	\$1,653	\$11,475	\$11,475
Low	Low	\$7,600	-\$479	\$3,898	\$1,653	\$5,551	\$5,551
High	High	\$10,000	-\$223	\$8,274	\$1,653	\$9,927	\$9,927

("-" represents savings to user; no government cost)

## Option 2B--Battery Electric Light-Duty Vehicles (Mature Market)

### INPUTS

	Unit	
<b>Fleet Information</b>		
Number of Vehicles		1
Fuel Consumption	kWh/Year	6,250
Daily Consumption	kWh/weekday	20

<b>Station Owner Information</b>		
ROI	%	12%
Investment Life	Year	20

<b>Capital Costs</b>		
Number of Stations	each	0
Station Upgrade cost (each)	Dollars	\$0
Station Upgrade Expenses (total)	\$	\$0

<b>Other Costs</b>		
StationGross Margin	\$/year	\$0
Import Fee	\$/Gallon	\$0.00
Annual Import Cost	\$/year	\$0

(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)

(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	Fuel Cost to Station Owner	Target Return on Capital	Annual Fuel Cost	Target Revenue from Fuel Sales	Target Fuel Price without Taxes	Fuel Price with Taxes
	\$/kWh	\$/year	\$/year	\$	\$/kWh	\$/kWh
Low consumer Cost	\$0.062	\$0	\$388	\$388	\$0.062	\$0.062
High Consumer Cost	\$0.135	\$0	\$844	\$844	\$0.135	\$0.135

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	Electricity	Gasoline	Diesel
LHV Energy Content =	3,412	112,000	126,000
CA Taxes =		\$0.18	\$0.24
Fed Taxes =		\$0.18	\$0.18
Total Exise Taxes =		\$0.36	\$0.42
Sales Taxes =		7.75%	7.75%

# Option 2B--Battery Electric City Car Vehicles (Mature Market)

## INPUTS

Fleet Information	Units	Electric Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1	Vehicles	1
Annual Mileage	Miles/Vehicle/Year	6,250	Miles/Vehicle/Year	6,250
Fuel Economy	Miles/kWh	2.0	Miles/Gallon	45.0
Fuel Consumption	kWh/Year	3,125	Gallons/Year	139
Daily Consumption	kWh/weekday	10	Gallons/weekday	0

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Electric Vehicle		Gasoline ICE Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$4,400	\$3,333	\$0	\$0
Total Incremental Vehicle Cost	\$	\$4,400	\$3,333	\$0	\$0

(Includes \$1,000 for infrastructure)

Fuel Costs	Units	Electricity		Gasoline	
		Higher Price Estimate	Lower Price Estimate	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/kWh & \$/gal	\$0.135	\$0.062	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$422	\$194	\$251	\$204

(Note: Lower Price Estimate is Discounted by 40%)

## OUTPUTS

Electric Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (EV-Gasoline)	Incremental Annual Fuel Cost (EV-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$3,333	-\$58	\$2,887	\$389	\$3,277	\$2,359	\$2,359
High	Low	\$4,400	\$218	\$6,081	\$389	\$6,470	\$4,659	\$4,659
Low	Low	\$3,333	-\$10	\$3,252	\$389	\$3,641	\$2,622	\$2,622
High	High	\$4,400	\$170	\$5,716	\$389	\$6,106	\$4,396	\$4,396

(Note: Assumes all "+" Consumer Costs paid by Government)

Electric Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (EV-Gasoline)	Incremental Annual Fuel Cost (EV-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$3,333	-\$58	\$2,887	\$389	\$3,277	\$3,277
High	Low	\$4,400	\$218	\$6,081	\$389	\$6,470	\$6,470
Low	Low	\$3,333	-\$10	\$3,252	\$389	\$3,641	\$3,641
High	High	\$4,400	\$170	\$5,716	\$389	\$6,106	\$6,106

("-" represents savings to user; no government cost)

## Option 2B--Battery Electric City Car Vehicles (Mature Market)

### INPUTS

Unit

#### Fleet Information

Number of Vehicles		1
Fuel Consumption	kWh/Year	3,125
Daily Consumption	kWh/weekday	10

#### Station Owner Information

ROI	%	12%
Investment Life	Year	20

#### Capital Costs

Number of Stations	each	0
Station Upgrade cost (each)	Dollars	\$0
Station Upgrade Expenses (total)	\$	\$0

#### Other Costs

Station Gasoline Gross Margin	\$/year	\$0	(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	\$/Gallon	\$0.00	
Gulf Coast to CA ADSL Annual Import Cost	\$/year	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	Fuel Cost to Station Owner	Target Return on Capital	Annual Fuel Cost	Target Revenue from Fuel Sales	Target Fuel Price without Taxes	Fuel Price with Taxes
	\$/kWh	\$/year	\$/year	\$	\$/kWh	\$/kWh
Low Consumer Cost	\$0.062	\$0	\$194	\$194	\$0.062	\$0.062
High Consumer Cost	\$0.135	\$0	\$422	\$422	\$0.135	\$0.135

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	Electricity	Gasoline	Diesel
LHV Energy Content =	3,412	112,000	126,000
CA Taxes =		\$0.18	\$0.24
Fed Taxes =		\$0.18	\$0.18
Total Exise Taxes =		\$0.36	\$0.42
Sales Taxes =		7.75%	7.75%

## **Option 2C**

### **Grid-Connected Hybrid Electric Vehicles**

**(Analysis by David Ashuckian)**

#### **Description**

This option would expand the use of grid-connected hybrid-electric vehicles (HEVs) to replace gasoline fueled light-duty vehicles.

#### **Background**

Grid-connected hybrid-electric vehicles (HEVs) have plug-in capabilities, a larger electric motor and larger batteries than non-grid-connected hybrid-electric vehicles. This allows them to achieve a portion of their travel on batteries alone. Given that approximately 63 percent of daily trips are less than 60 miles in length, grid-connected gasoline-electric hybrid vehicles with medium sized battery packs can completely replace one-half of all gasoline powered vehicle trips.<sup>1</sup> Grid-connected HEVs use the same batteries as electric battery vehicles (see Option 2B), but have a smaller battery pack and correspondingly lower incremental vehicle cost.

Recently revised “Zero Emission Vehicle” regulations adopted by ARB may encourage automobile manufacturers to re-examine the potential for grid-connected HEVs. If grid-connected hybrid vehicles become available, they could provide an additional reduction in petroleum use compared to conventional hybrid vehicles. However, developers still need to address battery and component costs and battery life, especially in this application with frequent shallow charging and discharging cycles.

#### **Assumptions and Methodology**

This estimate of petroleum reduction assumes that these vehicles would be included as a subset of the required sales for Advanced Technology Partial Zero Emission Vehicles (AT PZEVs). It also assumes that these vehicles would be able to achieve 30 miles per gallon of gasoline during engine operation. Current regulations require approximately 309,000 advanced technology PZEVs to be operating in California by 2010. Staff assumed that grid-connected hybrids could displace up to 63 percent of the annual vehicle miles traveled with all-electric operation, and that the fuel economy of these vehicles is 30 miles per gallon while operating on the gasoline engine during longer trips not served by electric-only operation.

The cost per mile of the 20-mile range HEV (called a HEV-20) and the cost per mile of the HEV-60 appear very similar, although the cost per mile of the HEV-60 is reported by EPRI to be somewhat lower than the HEV-20. Thus, staff analyzed the cost for a grid-connected HEV with a 60 mile range, although others have studied 20- and 40-mile ranges as well as 60-mile range vehicles. While the optimum “zero equivalent” range is still being determined, staff chose to evaluate the cost of the 60 mile range because the cost-effectiveness of the 60 mile vehicle seems slightly better than the 20 or 40 mile vehicles, based upon their incremental capital costs relative to a gasoline engine, and the corresponding volumes of gasoline displacement.

## Status of Grid-Connected Hybrid Electric Vehicles

The U. S. Department of Energy (DOE) is funding research and development of hybrid electric vehicles (not just grid-connected), focusing upon improved battery packs, system component optimization, reduced ancillary loads, advanced power electronics, hybrid/electric propulsion systems, Department of Defense needs, and advanced materials and architectures. DOE's Hybrid Systems R&D funding was \$41.8 million in Fiscal Year (FY) 2000, \$49.8 million in FY 2001 and a requested \$48.2 million in FY 2002.

Grid-connected HEVs are undergoing research at the Electric Power Research Institute (EPRI).<sup>2</sup> EPRI is focusing upon how electric grid operation can be enhanced using distributed technologies, including electric-drive vehicles such as grid-connected HEVs. EPRI is also working with automobile manufacturers and the Department of Defense to examine the potential for grid-connected HEVs, among others.

Grid-connected HEVs are also an element in a Vehicle-to-Grid (V-2-G) Power study conducted by the University of Delaware.<sup>3</sup> This latter study indicates potentially very significant market potential for grid-connected HEVs. However, several aspects need further work, including better estimates of incremental vehicle cost, durability of batteries when used in this mode, user behavior, and other factors. Their most recent proposal is to evaluate the market potential for V-2-G operation, focusing on driver behavior and battery degradation.<sup>4</sup>

A form of Ancillary Services (A/S), called "regulation services" shows particularly strong potential, for being served by grid-connected electric-drive vehicles, since in this mode batteries would be equally charged and discharged, conserving battery energy. Ancillary services have historically been about 5 percent of the California ISO's energy costs, costing about \$1.3 billion in the first 10 months of 2001.<sup>5</sup> However, other issues await evaluation, including the market potential for other nontraditional sources of ancillary services.

The largest cost component for grid-connected hybrid electric vehicles is associated with the battery. This is tied directly to the incremental vehicle capital cost, and the degree to which they can displace gasoline vehicle operation. The Air Resources Board's Advanced Battery Panel expects the per vehicle cost of batteries to be \$13,000 to \$20,000 in production quantities of 100,000 per year, reducing to about \$7,000 per vehicle with additional research and development and even greater annual production.<sup>6</sup> See Option 2B for more discussion of battery development research and funding. For the purposes of the analysis reported below, staff used the EPRI battery cost of \$270 per kWh.

## Results

**Intermediate Market.** First staff evaluated the life cycle costs of HEVs assuming costs appropriate for an intermediate market, before volume production has reduced battery and other component costs to the lower levels of a mature market (see below). To reach the mature market by 2030, the grid-connected hybrid electric vehicle population is assumed to transition through

an intermediate market, reaching 4 percent of the light-duty vehicle population by 2020. Capital costs for this market condition were derived from the EPRI study.

**Table 2C-1. Intermediate Market, Grid-Connected Hybrid-Electric Battery Vehicle Life Cycle Costs**

Grid-connected HEVs	Gasoline ICE Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	9,500	-597	4,894	1.04	1.04
Low	Low	9,500	-396	6,442	1.30	1.30
High	High	14,700	-257	12,719	2.36	2.36
High	Low	14,700	-56	14,266	2.63	2.63

Note that these costs are compared to a gasoline vehicle and the “gallon” unit is a displaced gallon of gasoline. Negative values are savings and positive values are additional costs compared to gasoline. Note also that government loses \$1,221 per vehicle in excise taxes, per year.

**Mature Market.** Staff evaluated the lifecycle cost of grid-connected HEVs in terms of vehicle owner costs and government costs, assuming that vehicle related R&D cost and performance targets are met. Staff assumed that 63 percent of their vehicle miles of travel could be in a battery-only mode, at 60 miles per charge. Staff also assumed a range of 6.2 to 13.5 cents per kWh for the cost of recharging the vehicle battery pack. This is the range of residential retail prices estimated for the PG&E, SCE, SDG&E, LADWP and SMUD service territories by the California Energy Commission, with the lower value discounted by 40 percent to reflect off-peak charging,<sup>7</sup> as discussed in Option 2B. Fuel excise taxes are assumed to be zero, representing a loss to the government. Staff assumed continuation of the existing practice of no excise taxes on electricity used in transportation and included the loss of revenue in the overall cost to government.

Using the Retail Price Equivalent comparison developed by the Electric Power Research Institute for a Grid Connected Hybrid Electric Vehicle that has a 60 mile all electric range, the cost of grid connected HEV-60 in a mature market was estimated to range between \$7,000 and \$10,200 per vehicle.<sup>8</sup> Vehicle owners will probably have to pay more for a grid-connected HEV than a comparable gasoline ICE, even if R&D targets are met. Since staff assumed continuation of existing fuel excise taxes, government would lose excise tax revenue because of fewer gallons of fuel sold, due to the assumed displacement of gasoline consumption by the grid-connected HEVs. Government excise taxes lost are estimated at \$893 per vehicle year. Staff also assumed that government absorbs any net cost increases incurred by the vehicle owner. Results are shown in net present value 2002 dollars over an assumed 10-year vehicle life, discounted at 12 percent real, except for the incremental capital costs which are already in present value.

At the incremental vehicle and fuel costs assumed, the grid-connected HEV costs more to own and operate than the gasoline ICE vehicle. The Government Costs are equal to the Overall Cost because it is assumed that government pays for all cost increases.

**Table 2C-2. Mature Market, Grid-Connected Hybrid-Electric Battery Vehicle Life Cycle Costs**

Grid-connected HEVs	Gasoline ICE Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	7,000	-434	3,650	0.83	0.83
Low	Low	7,000	-233	5,198	1.09	1.09
High	High	10,200	-257	8,219	1.60	1.60
High	Low	10,200	-56	9,766	1.86	1.86

Note that these costs are compared to a gasoline vehicle and the “gallon” unit is a displaced gallon of gasoline. Negative values are savings and positive values are additional costs compared to gasoline. Government loses \$1,221 per year in excise taxes.

In their study, the University of Delaware calculated some value-added benefit for using grid-connected HEVs to provide A/S and other forms of grid support. However, these additional benefits are not included here because staff believes the University of Delaware cost estimates were incomplete. Furthermore, their study did not evaluate competing technologies that might provide these services at lower cost. If grid-connected HEVs are able to provide A/S and realize some value-added benefit, it is possible that a portion, or even all of the net costs in the table above could be offset.

**Gasoline Displacement.** Staff assumed that a mature market for grid-connected HEVs develops by 2030, displacing gasoline ICE vehicles by 10 percent. To reach that level of market penetration by 2030, staff assumed they displace 4 percent of the market by 2020.

**Table 2C-3. Gasoline Displaced by Grid-Connected HEVs**

	Annual Petroleum Reduction		
	2010	2020	2030
Annual Reduction in Gasoline Consumption (million gallons)	N/A	470	1,360
Reduction From Base Case Demand (Percent)	N/A	2.5	6.3

### Key Drivers and Uncertainties

There is uncertainty in the likelihood that additional research funding can reduce the cost of manufacturing advanced batteries for grid-connected hybrid electric vehicles. There is also uncertainty in consumer interest in purchasing a grid-connected hybrid electric vehicle that would still have a higher cost compared to hybrid-electric vehicle or conventional gasoline powered vehicle. There is also uncertainty in manufacturer interest in producing grid-connected hybrid electric vehicles. Finally, there is uncertainty whether grid-connected HEVs could achieve additional revenue in a V-2-G application and the resulting impact on cost effectiveness over the life of the vehicle. If the V-2-G does lead to reduced life-cycle costs, the market may develop in a more accelerated pace, with lower lifecycle costs.

---

<sup>1</sup> Society of Automotive Engineers, Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles SAE J1711 (March 1999).

<sup>2</sup> Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options, EPRI, Palo Alto, CA: 2001 1000349.

<sup>3</sup> Vehicle-to-Grid Power: Battery, Hybrid and Fuel Cell Vehicles as Resources for Distributed Electric Power in California, June 2001.

<sup>4</sup> Preproposal, Personal Electric Drive Vehicles for Vehicle-to-Grid Power: Development of Missing parameters and User Interface, February 8, 2002.

<sup>5</sup> Vehicle to Grid—A Control Area Operators Perspective, David Hawkins, California Independent System Operator, December 3, 2001.

<sup>6</sup> Performance and Availability of Batteries for Electric Vehicles: A Report of the Battery Technical Advisory Panel, December 11, 1995 Prepared for the California Air Resources Board.

<sup>7</sup> 2002—2012 Electricity Outlook Report, P700-01-004F, February 2002, Table III-2-4, adjusted to 2002 dollars.

<sup>8</sup> Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options, EPRI, Palo Alto, CA: 2001 1000349.

Option 2C--Grid-Connected Hybrids, Intermediate Market

INPUTS

Fleet Information	Units	EV Mode HEV	Units	Gasoline Mode HEV	Gasoline Vehicle
Number of Vehicles	Vehicles	1	Vehicles	1	1
Annual Mileage	Miles/Vehicle/Year	7,875	Miles/Vehicle/Year	4,625	12,500
Fuel Economy	Miles/kWh	2.0	Miles/Gallon	30.0	21.2
Fuel Consumption	kWh/Year	3,938	Gallons/Year	154	590
Daily Consumption	kWh/weekday	13	Gallons/weekday	0.5	2

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Hybrid Electric Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$14,700	\$9,500	\$0	\$0
Total Incremental Vehicle Cost	\$	\$14,700	\$9,500	\$0	\$0

Fuel Costs	Units	Electricity		Gasoline	
		Higher Price Estimate	Lower Price Estimate	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/kWh & \$/gal	\$0.135	\$0.062	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$811	\$471	\$1,067	\$867

(Note: Low Price Estimate is Discounted 40%)

OUTPUTS

H-E Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (HEV-Gasoline)	Incremental Annual Fuel Cost (HEV-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$9,500	-\$597	\$4,894	\$1,221	\$6,114	\$1.04	\$1.04
High	Low	\$14,700	-\$56	\$14,266	\$1,221	\$15,487	\$2.63	\$2.63
Low	Low	\$9,500	-\$396	\$6,442	\$1,221	\$7,662	\$1.30	\$1.30
High	High	\$14,700	-\$257	\$12,719	\$1,221	\$13,939	\$2.36	\$2.36

H-E Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (HEV-Gasoline)	Incremental Annual Fuel Cost (HEV-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$9,500	-\$597	\$4,894	\$1,221	\$6,114	\$6,114
High	Low	\$14,700	-\$56	\$14,266	\$1,221	\$15,487	\$15,487
Low	Low	\$9,500	-\$396	\$6,442	\$1,221	\$7,662	\$7,662
High	High	\$14,700	-\$257	\$12,719	\$1,221	\$13,939	\$13,939

("-" represents savings to user; no government cost)

## Option 2C--Grid-Connected Hybrids, Intermediate Market

### INPUTS

Unit

#### Fleet Information

Number of Vehicles		1
Fuel Consumption	kWh/Year	3,938
Daily Consumption	kWh/weekday	13

#### Station Owner Information

ROI	%	12%
Investment Life	Year	20

#### Capital Costs

Number of Stations	each	0
Station Upgrade cost (each)	Dollars	\$0
Station Upgrade Expenses (total)	\$	\$0

#### Other Costs

Station Gasoline Gross Margin	\$/year	\$0	(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	\$/Gallon	\$0.00	
Gulf Coast to CA LPG Annual Import Cost	\$/year	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	Fuel Cost to Station Owner	Target Return on Capital	Annual Fuel Cost	Target Revenue from Fuel Sales	Target Fuel Price without Taxes	Fuel Price with Taxes
	\$/kWh	\$/year	\$/year	\$	\$/kWh	\$/kWh
Low Consumer Cost	\$0.065	\$0	\$256	\$256	\$0.065	\$0.065
High Consumer Cost	\$0.135	\$0	\$532	\$532	\$0.135	\$0.135

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	Electricity	Gasoline	Diesel
LHV Energy Content =	3,142	112,000	126,000
CA Taxes =	\$0.000	\$0.18	\$0.24
Fed Taxes =	\$0.000	\$0.18	\$0.18
Total Exise Taxes =	\$0.000	\$0.36	\$0.42
Sales Taxes =	0.00%	7.75%	7.75%

Option 2C--Grid-Connected Hybrids, Mature Market

INPUTS

Fleet Information	Units	EV Mode HEV	Units	Gasoline Mode HEV	Gasoline Vehicle
Number of Vehicles	Vehicles	1	Vehicles	1	1
Annual Mileage	Miles/Vehicle/Year	7,875	Miles/Vehicle/Year	4,625	12,500
Fuel Economy	Miles/kWh	2.0	Miles/Gallon	30.0	21.2
Fuel Consumption	kWh/Year	3,938	Gallons/Year	154	590
Daily Consumption	kWh/weekday	13	Gallons/weekday	0.5	2

Fleet Owner Information	Units				
Capital Amortization Rate	%	5%			
Vehicle Life	Year	10			
Payback Period	Year	10			
Vehicle Capital Costs	Units	Hybrid Electric Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$10,200	\$7,000	\$0	\$0
Total Incremental Vehicle Cost	\$	\$10,200	\$7,000	\$0	\$0

Fuel Costs	Units	Electricity		Gasoline	
		Higher Price Estimate	Lower Price Estimate	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/kWh & \$/gal	\$0.135	\$0.103	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$811	\$633	\$1,067	\$867

(Note: Lower Price Estimate is Discounted 40%)

OUTPUTS

H-E Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (HEV-Gasoline)	Incremental Annual Fuel Cost (HEV-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$7,000	-\$434	\$3,650	\$1,221	\$4,871	\$0.83	\$0.83
High	Low	\$10,200	-\$56	\$9,766	\$1,221	\$10,987	\$1.86	\$1.86
Low	Low	\$7,000	-\$233	\$5,198	\$1,221	\$6,419	\$1.09	\$1.09
High	High	\$10,200	-\$257	\$8,219	\$1,221	\$9,439	\$1.60	\$1.60

H-E Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (HEV-Gasoline)	Incremental Annual Fuel Cost (HEV-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$7,000	-\$434	\$3,650	\$1,221	\$4,871	\$4,871
High	Low	\$10,200	-\$56	\$9,766	\$1,221	\$10,987	\$10,987
Low	Low	\$7,000	-\$233	\$5,198	\$1,221	\$6,419	\$6,419
High	High	\$10,200	-\$257	\$8,219	\$1,221	\$9,439	\$9,439

("-" represents savings to user; no government cost)

## Option 2C--Grid-Connected Hybrids, Mature Market

### INPUTS

Unit

#### Fleet Information

Number of Vehicles		1
Fuel Consumption	kWh/Year	3,938
Daily Consumption	kWh/weekday	13

#### Station Owner Information

ROI	%	12%
Investment Life	Year	20

#### Capital Costs

Number of Stations	each	0
Station Upgrade cost (each)	Dollars	\$0
Station Upgrade Expenses (total)	\$	\$0

#### Other Costs

Station Gasoline Gross Margin	\$/year	\$0	(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	\$/Gallon	\$0.00	
Gulf Coast to CA LPG Annual Import Cost	\$/year	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	Fuel Cost to Station Owner	Target Return on Capital	Annual Fuel Cost	Target Revenue from Fuel Sales	Target Fuel Price without Taxes	Fuel Price with Taxes
	\$/kWh	\$/year	\$/year	\$	\$/kWh	\$/kWh
Low Consumer Cost	\$0.065	\$0	\$256	\$256	\$0.065	\$0.065
High Consumer Cost	\$0.135	\$0	\$532	\$532	\$0.135	\$0.135

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	Electricity	Gasoline	Diesel
LHV Energy Content =	3,142	112,000	126,000
CA Taxes =	\$0.000	\$0.18	\$0.24
Fed Taxes =	\$0.000	\$0.18	\$0.18
Total Exise Taxes =	\$0.000	\$0.36	\$0.42
Sales Taxes =	0.00%	7.75%	7.75%

## **Option 2D**

### **CNG for Light Duty Vehicles**

**(Analysis by David Ashuckian)**

#### **Description**

This option would provide purchase incentives for Compressed Natural Gas (CNG) light-duty vehicles and funding to support installation of public infrastructure to support a growing fleet of light-duty CNG vehicles.

#### **Background**

Manufacturers have offered light-duty CNG vehicles in California for a number of years. Approximately 2,000 light-duty compressed natural gas vehicles are sold each year to fleet operators and private consumers. The lack of availability of public infrastructure, the additional cost of these vehicles, and reduced driving range have limited the market penetration of this technology.

#### **Assumptions and Methodology**

We assume that a home refueling device is produced and manufacturers increase production of CNG vehicle models, compared to our base case. CNG light-duty vehicles displace gasoline light-duty vehicles that average 21.2 miles per gallon.

#### **Status of Light Duty Vehicles**

These vehicles are commercially available, although in limited quantities. To date, incremental life cycle costs have been too high to increase market penetration.

#### **Results**

**Intermediate Market.** Light-duty CNG vehicles appear to be market ready at this time. We believe they will penetrate the gasoline vehicle market once their more costly vehicle purchase prices are offset by fuel and other operational savings. To date, this has not been the case and sales have been limited. Staff assumed that light-duty CNG vehicles incremental costs are reduced from today's \$4,500 to \$7,500 per vehicle to a lower range of \$3,000 to \$5,500 per vehicle. Due to the limited range associated with CNG vehicles, staff assumed the need of a home refueling unit, at an additional \$1,000 per vehicle.

The number of fueling stations needed for the intermediate market is assumed to be adequate to meet the total number of vehicles, with stations large enough to handle a maximum number of vehicles with a minimum number of stations. Assuming a high-use rated station with each filling station or pump, handling 40,000 therms per month (32,000 gasoline gallon equivalents) or 384,000 gasoline gallon equivalents per year would require approximately 50,000 filling pumps. Assuming that each full station has on average 5 pumps results in 10,000 stations, approximately

the same number of gasoline stations that are currently operating in California. The costs for the largest CNG stations currently operating run approximately \$600 per standard cubic foot minute. This would result in a cost of approximately \$553,000 per refueling facility, excluding land acquisition costs.

**Table 2D-1. Intermediate Market Compressed Natural Gas Vehicles**

CNG Vehicles	Gasoline ICE Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	4,000	-400	912	0.34	0.34
Low	Low	4,000	-199	2,460	0.61	0.61
High	High	5,500	-109	4,657	0.98	0.98
High	Low	5,500	91	6,205	1.24	1.24

Note that these costs are compared to a gasoline vehicle and the “gallon” unit is a displaced gallon of gasoline. Negative values are savings and positive values are additional costs compared to gasoline.

**Mature Market.** Staff assumed the same costs and refueling conditions for the mature market. See above for results.

**Gasoline Displacement.** The following table summarizes the amount of gasoline displaced by compressed natural gas in the target years shown.

**Table 2D-2. Intermediate Market Compressed Natural Gas Petroleum Reduction**

	Annual Gasoline Reduction		
	2010	2020	2030
Annual Reduction in Gasoline Consumption (million gallons)	650	1,870	N/A
Reduction From Base Case Demand (Percent)	4	10	N/A

### Key Drivers and Uncertainties

There is uncertainty in number of vehicles that consumers would purchase given that CNG vehicles have a reduced range compared to conventional gasoline powered vehicles. There is uncertainty in the development and production of a home-refueling device that would meet consumer needs. There is uncertainty in the cost of large quantities of CNG stations and uncertainty in manufacturer interest in producing additional numbers of CNG vehicles.

Option 2D--CNG Light-Duty Vehicles--Intermediate and Mature Markets

INPUTS

Fleet Information	Units	CNG Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	30,685	Vehicles	30,685
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/GGE	17.6	Miles/Gallon	21.2
Fuel Consumption	GGE/Year	21,793,324	Gallons/Year	18,092,571
Daily Consumption	GGE/weekday	69,850	Gallons/weekday	57,989

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	CNG Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$5,500	\$4,000	\$0	\$0
Total Incremental Vehicle Cost	\$	\$168,767,500	\$122,740,000	\$0	\$0

Fuel Costs	Units	CNG		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/GGE & \$/gal	\$1.35	\$0.94	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$29,399,176	\$20,475,900	\$32,747,553	\$26,596,079

OUTPUTS

CNG Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (CNG-Gasoline)	Incremental Annual Fuel Cost (CNG-Gasoline)	Present Value Consumer Costs (" " Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$122,740,000	-\$12,271,653	\$27,981,545	\$34,221,628	\$62,203,173	\$0.344	\$0.344
High	Low	\$168,767,500	\$2,803,097	\$190,412,272	\$34,221,628	\$224,633,901	\$1.242	\$1.242
Low	Low	\$122,740,000	-\$6,120,179	\$75,481,597	\$34,221,628	\$109,703,225	\$0.606	\$0.606
High	High	\$168,767,500	-\$3,348,377	\$142,912,220	\$34,221,628	\$177,133,848	\$0.979	\$0.979

CNG Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (CNG-Gasoline)	Incremental Annual Fuel Cost (CNG-Gasoline)	Present Value Consumer Cost Net Present Value (" " Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$4,000	-\$400	\$912	\$1,115	\$2,027	\$2,027
High	Low	\$5,500	\$91	\$6,205	\$1,115	\$7,321	\$7,321
Low	Low	\$4,000	-\$199	\$2,460	\$1,115	\$3,575	\$3,575
High	High	\$5,500	-\$109	\$4,657	\$1,115	\$5,773	\$5,773

(" " represents savings to user; no government cost)

## Option 2D--CNG Light-Duty Vehicles

### INPUTS

#### Unit

#### Fleet Information

Number of Vehicles		30,685
Fuel Consumption	<b>GGE/Year</b>	21,793,324
Daily Consumption	<b>GGE/weekday</b>	69,850

#### Station Owner Information

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

#### Capital Costs

Number of Stations	<b>each</b>	10
Station Upgrade cost (each)	<b>Dollars</b>	\$553,000
Station Upgrade Expenses (total)	<b>\$</b>	\$5,530,000

#### Other Costs

Station Gasoline Gross Margin	<b>\$/year</b>	\$0	(assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00	
Gulf Coast to CA Annual Import Cost	<b>\$/year</b>	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low CNG Wholesale Cost	\$0.74	\$740,350	\$16,127,060	\$16,867,409	\$0.77	\$0.94
High CNG Wholesale Cost	\$1.12	\$740,350	\$24,408,523	\$25,148,872	\$1.15	\$1.35

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	<b>CNG</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	93,000	112,000	126,000
CA Taxes =	\$0.058	\$0.18	\$0.24
Fed Taxes =	\$0.040	\$0.18	\$0.18
Total Exise Taxes =	\$0.098	\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

## **Option 2E**

### **Liquefied Petroleum Gas (LPG)**

**(Analysis by Gerry Bemis)**

#### **Description**

This option examines the effect of liquefied petroleum gas (LPG) fuel displacing gasoline in light- and medium-duty vehicles over the 2002 to 2030 time period. Government incentives would lead the retrofit kit market to grow in the near-term and vehicle manufacturers to offer a LPG option for new vehicles in the mid- and long-term.

#### **Background**

Propane, the major ingredient of LPG, is a colorless, odorless, tasteless and non-toxic hydrocarbon. It has a narrow flammability limit compared to gasoline and is considered a safer fuel, but garages and repair facilities need proper ventilation.<sup>1</sup> It is pressurized for use in vehicles and stored in special fuel tanks as a liquid that vaporizes to a gas before being burned in an engine. According to the Western Propane Gas Association, there were 1,200 LPG refueling facilities in California in 2001, and half of these were capable of refueling vehicles. Because of its many uses (i.e., space heating, barbecues, forklifts and recreational vehicles), refueling modest numbers of LPG vehicles can be self-sustaining with little or no government support.<sup>2</sup>

In California, approximately one-half of the LPG supply is a byproduct of crude oil refining and the remainder is a byproduct of removing natural gas liquids at the wellhead of gas produced in California. Even though half of California's supply derives from crude oil, staff included LPG in this analysis because it is capable of displacing gasoline and because it is a byproduct of refining crude oil, not the main product. LPG is comprised primarily of propane and butane, with small amounts of other natural gas and petroleum byproducts.

#### **Assumptions and Methodology**

Staff evaluated the potential for using LPG to displace gasoline light-duty vehicles. Staff assumed OEMs offer LPG as a factory option for new light-duty vehicles. Staff assumed existing federal LPG excise taxes (13.6 cents per gallon) and state LPG excise taxes (6.0 cents per gallon) continue, and calculated excise tax revenue lost to the government and other program costs to determine total government costs.

#### **Status of LPG Fueled Vehicles**

LPG is one of the most widely used transportation fuels used today, except for gasoline and diesel. In 2000, there were about 268,000 LPG vehicles operating in the United States, including 33,000 in California.<sup>3</sup> This is estimated to be over 60 percent of all operating alternative fuel vehicles that use non-petroleum fuels (excludes Fuel Flexible Vehicles operating on gasoline). California's fleet represents about 12.3 percent of the nation's LPG vehicles. About 60 percent of the LPG vehicles are pickup trucks, taxis, buses, airport shuttles and forklifts. In 1999, about

0.4 percent of the LPG used nationwide was for transportation, while California used 3.2 percent of its LPG for transportation.<sup>4</sup> Nationwide in 1999, 78 percent of the LPG use was in industrial applications.

The propane supply industry indicates that three types of Original Equipment Manufacturer (OEM) vehicles are currently for sale in California:<sup>5</sup>

- Ford F-150 bi-fuel pickup truck (California Department of Transportation has 700-800 of them, mostly fueled with gasoline, not LPG).
- General Motors (GM) medium-duty LPG truck (these have been available for about 10 years and California sales are estimated at about 1,000 since 1998).
- Cummins B-Series engines, which can be used in pick-ups and shuttle buses.
- LPG-fueled GM shuttle van, which is just now entering the market, with GM awaiting more orders before launching production.

There are currently no LPG retrofit kits certified by the Air Resources Board for sale in California, although the industry hopes to have at least one kit certified beginning in 2002 and hopes to sell about 200 per year in California. Historical vehicle conversion costs for light-duty vehicles were approximately \$1,900 to \$2,900 per vehicle (converted to 2002 \$).<sup>6</sup> Typical retrofit includes a 40 to 60 gallon tank (30 to 44 gallon gasoline equivalent) and vehicle refueling takes 3-5 minutes. Typical existing refueling station storage tanks are 500 to 1,000 gallons, but 30,000-gallon tanks are also in use. Adding a 6,000-gallon underground LPG tank to an existing gasoline refueling station is estimated to cost \$100,000.<sup>7</sup>

LPG fuel sales volumes and prices peak in the wintertime for space heating, and a significant transportation use would tend to level them out. However, if the demand grows too rapidly, existing wintertime peak prices could intensify. This analysis assumes that growth in LPG use for transportation does not cause wintertime market price peaks to intensify because a long-term import market would be established.

## Results

**Intermediate Market.** To obtain representative, near-term costs, staff assessed the life-cycle costs of owning and operating a medium-duty van. Staff assumed initial sales occur in 2004. Staff assumed these vehicles operate 20,000 miles per year when new, decreasing to zero miles per year after 10 years of life. Medium-duty LPG vehicles are assumed to travel 9 miles per gallon of LPG, displacing comparably sized gasoline vehicles that travel 12 miles per gallon of gasoline. The incremental cost of a medium-duty LPG vehicle is assumed to be \$2,000 to \$4,000 per vehicle, due to the larger size needed for this vehicle class compared to costs for a light-duty vehicle.

Since staff assumed continuation of existing fuel excise tax policies, government would lose excise tax revenue because of fewer gallons of gasoline sold, due to the assumed displacement of

gasoline. However, staff also assumed that government absorbs any net cost increases incurred by the vehicle owner. Results are shown in net present value 2002 dollars, over an assumed 10-year vehicle life, discounted at 5 percent real except for incremental capital costs, which are already in net present value terms.

**Table 2E-1. Intermediate Market Medium-Duty LPG Vehicles**

LPG Medium Duty Vehicles	Gasoline Medium Duty Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	2,000	-807	-4,231	0.03	-0.22
Low	Low	2,000	-240	145	0.04	0.04
High	High	4,000	-147	2,867	0.20	0.20
High	Low	4,000	420	7,243	0.46	0.46

Note that these costs are compared to a gasoline vehicle and the “gallon” unit is a displaced gallon of gasoline. Negative values are savings and positive values are additional costs compared to gasoline. Government loses \$502 in excise taxes per vehicle per year.

When LPG vehicle and fuel prices are low and corresponding gasoline prices are high, each year the consumer saves \$4,231 per vehicle, as shown on the table. When the reverse occurs, the consumer spends an extra \$7,243 per vehicle. The annual cost to government under this scenario ranges from a low of \$502 per vehicle (in lost excise taxes) to a high of \$7,745 per vehicle (if the government underwrites \$7,243 per year in extra consumer fuel costs, while also losing \$502 per vehicle in excise taxes). These results would occur if LPG prices are uncoupled from gasoline prices, and LPG prices are high while gasoline prices are low. Historical national average LPG prices do track somewhat with gasoline prices. For the 1984 to 2000 time period, annual average LPG prices show a 23 percent correlation ( $R^2=0.23$ ) and monthly prices for the 2000-2001 time period show a 59 percent correlation ( $R^2=0.59$ ). Therefore, the costs in the second and third rows of the table are more likely.

**Mature Market.** To obtain life cycle costs for a mature market, staff assumed widespread sales of light-duty vehicles. Staff assumed that government incentives are used to encourage OEMs to offer vehicles with a Liquefied Petroleum Gas (LPG) option. Near term light-duty LPG vehicle incremental costs are \$2,900 but as the market continues to develop between 2010 and 2020, the incremental vehicle cost reduces to \$200, mostly for a pressurized fuel tank. As vehicle sales increase, some gasoline station owners decide to install 6,000-gallon underground storage tanks at a cost of \$100,000 per station.

By about the year 2020, one half of the nation’s growth in LPG fuel supply (growth from 2002) serves the growing California LPG transportation market. This fuel is attracted to California by paying up to \$0.20 per gallon premium in the wholesale market to purchase LPG and transport it to California. This volume of LPG is sufficient to displace about 10 percent of the gasoline vehicles in the year 2020. Correspondingly, by then 10 percent of the refueling sites install new LPG tanks. Competition forces both gasoline and LPG prices to fall, with the LPG offered at a price sufficiently below gasoline to ensure its continued market. By the year 2020, 3.2 million

LPG vehicles are on the road, consuming 2.5 billion gallons of LPG, displacing 1.9 billion gallons of gasoline.

**Table 2E-2. Mature Market Light-Duty LPG Vehicles**

LPG Medium Duty Vehicles	Gasoline Medium Duty Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	200	-269	-1,875	0.02	-0.29
Low	Low	200	-68	-327	0.02	-0.03
High	High	2,900	-34	2,640	0.47	0.47
High	Low	2,900	167	4,188	0.74	0.74

Note that these costs are compared to a gasoline vehicle and the “gallon” unit is a displaced gallon of gasoline. Negative values are “savings” and positive values are “additional costs” compared to gasoline. Government loses \$150 in excise taxes per vehicle per year.

When LPG vehicle and fuel prices are low and corresponding gasoline prices are high, each year the consumer saves \$1,875 per vehicle, as shown on the table. When the reverse occurs, the consumer spends an extra \$4,188 per vehicle. The annual cost to government under this scenario ranges from a low of \$150 per vehicle (consumers save \$1,875 per vehicle while the government loses \$150 per vehicle per year in excise taxes) to a high of \$4,338 per vehicle (if the government underwrites \$4,188 per year in extra consumer fuel costs and loses \$150 per vehicle in excise taxes). This result would occur if LPG prices are uncoupled from gasoline prices, and LPG prices are high while gasoline prices are low. Historical national average LPG prices do track somewhat with gasoline prices. For the 1984 to 2000 time period, annual average LPG prices show a 23 percent correlation ( $R^2=0.23$ ) and monthly prices for the 2000-2001 time period show a 59 percent correlation ( $R^2=0.59$ ). Therefore, the costs in the second and third rows of the table are more likely.

Assuming LPG and gasoline fuel prices are coupled and are high at the same time and low at the same time, each year consumers save \$327 per vehicle when fuel prices are low and spend an extra \$2,640 per vehicle when prices are high. Correspondingly, annual costs to government range from \$150 per vehicle when prices are low to \$2,790 per vehicle when prices are high and government pays the consumer for the extra fuel costs and loses \$150 per vehicle in excise taxes. Values for Change in Excise Tax, Government Cost per Gallon and Dollars per Gallon Displaced are all present value dollars for the assumed 10-year period of the life of the LPG vehicle.

**Gasoline Displacement.** Staff assumed that a mature market for LPG in medium- and light-duty vehicles develops by 2020, displacing gasoline ICE vehicles by 10 percent. To reach that level of market penetration by 2020, staff assumed they displace 4 percent of the market by 2010.

**Table 2E-3. Mature Market Gasoline Displacement**

	Annual Gasoline Reduction		
	2010	2020	2030
Annual Reduction in Gasoline Consumption (million gallons)	650	1,870	N/A
Reduction From Base Case Demand (Percent)	4	10	N/A

**Key Drivers and Uncertainties**

For the intermediate market, key drivers would be the availability of new OEM vehicles and CARB-certified retrofit kits for medium-duty vehicles. As stated above, there are few retrofit kits currently available. Also, the incremental vehicle price and the price of LPG must lead to life cycle costs sufficiently below that of a gasoline vehicle to re-stimulate this market. The price of LPG is estimated to range from \$1.01 to \$1.31 per gallon (\$1.35 to \$1.76 per gallon of gasoline equivalent) compared to gasoline prices ranging from \$1.47 to \$1.81 per gallon. Thus, depending on relative fuel prices, a subsidy may be required to reduce the price of the LPG option sufficiently to increase sales.

For the mature market scenario, additional key drivers include the assumption that OEMs will be induced to offer a sufficient number of their light-duty vehicles with a LPG option because of the government incentives and/or fuel price supports and the amount of LPG that could be “bid away” from other uses at an assumed delivered wholesale price increase of 20 cents per gallon. The timing of the advent of the mature market is also an uncertainty.

The likelihood of either of these scenarios to occur depends on the interplay of LPG and gasoline prices. Low LPG prices are unlikely to persist with corresponding high gasoline prices. When the fuel prices move in a coupled fashion, consumer benefits are fairly modest.

---

<sup>1</sup> Alternative Fuels: Emissions, Economics, and Performance, Society of Automotive Engineers, Inc., page 57.

<sup>2</sup> Information provided by Steve Moore of Mutual Liquid Gas, and compiled by A. D. Little for the CEC's *Clean Fuels Market Assessment*, 2001.

<sup>3</sup> U.S. DOE, Energy Information Administration web site: <http://www.eia.doe.gov/cneaf/alternate/page/datatables/table1.html>.

<sup>4</sup> U.S. DOE, Energy Information Administration, State Energy Data Report for 1999 (latest available).

<sup>5</sup> Personal communication, Bill Platz, Delta Liquid Energy.

<sup>6</sup> Alternative Motor Fuels—A Non-Technical Guide, PennWell Publishing (1996).

<sup>7</sup> California Clean Fuels Market Assessment 2001, CEC Publication P600-01-018 (September 2001).

Option 2E-- Intermediate LPG Market (Medium-Duty Vehicles)

INPUTS

Fleet Information	Units	LPG Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1,000	Vehicles	1,000
Annual Mileage	Miles/Vehicle/Year	20,000	Miles/Vehicle/Year	20,000
Fuel Economy	Miles/Gallon	9.0	Miles/Gallon	12.0
Fuel Consumption	Gallons/Year	2,222,222	Gallons/Year	1,666,667
Daily Consumption	Gallons/weekday	7,123	Gallons/weekday	5,342

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	LPG Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$4,000	\$2,000	\$0	\$0
Total Incremental Vehicle Cost	\$	\$4,000,000	\$2,000,000	\$0	\$0

Fuel Costs	Units	LPG		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.29	\$0.99	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$2,869,953	\$2,209,750	\$3,016,667	\$2,450,000

OUTPUTS

LPG Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (LPG-Gasoline)	Incremental Annual Fuel Cost (LPG-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$2,000,000	-\$806,916	-\$4,230,794	\$501,913	\$501,913	-\$0.224	\$0.030
High	Low	\$4,000,000	\$419,953	\$7,242,768	\$501,913	\$7,744,681	\$0.465	\$0.465
Low	Low	\$2,000,000	-\$240,250	\$144,855	\$501,913	\$646,768	\$0.039	\$0.039
High	High	\$4,000,000	-\$146,713	\$2,867,118	\$501,913	\$3,369,031	\$0.202	\$0.202

(Note: Assumes all "+" Consumer Costs are paid by Government)

LPG Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (LPG-Gasoline)	Incremental Annual Fuel Cost (LPG-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$2,000	-\$807	-\$4,231	\$502	\$502	-\$3,729
High	Low	\$4,000	\$420	\$7,243	\$502	\$7,745	\$7,745
Low	Low	\$2,000	-\$240	\$145	\$502	\$647	\$647
High	High	\$4,000	-\$147	\$2,867	\$502	\$3,369	\$3,369

("-" represents savings to user; no government cost)

## Option 2E-- Intermediate LPG Market (Medium-Duty Vehicles)

### INPUTS

Unit

#### Fleet Information

Number of Vehicles		1,000
Fuel Consumption	<b>Gallons/Year</b>	2,222,222
Daily Consumption	<b>Gallons/weekday</b>	7,123

#### Station Owner Information

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

#### Capital Costs

Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$100,000
Station Upgrade Expenses (total)	<b>\$</b>	\$100,000

#### Other Costs

Revenue from Retail Mark-Up	<b>\$/year</b>	\$333,333	(assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.15	
Gulf Coast to CA LPG Annual Import Cost	<b>\$/year</b>	\$446,721	(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low LPG Wholesale Cost	\$0.32	\$13,388	\$1,497,424	\$1,510,812	\$0.68	\$0.99
High LPG Wholesale Cost	\$0.60	\$13,388	\$2,110,142	\$2,123,530	\$0.96	\$1.29

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	<b>LPG</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	83,572	112,000	126,000
CA Taxes =	\$0.060	\$0.18	\$0.24
Fed Taxes =	\$0.183	\$0.18	\$0.18
Total Exise Taxes =	\$0.243	\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

cents/gallon			
Annual			
W'sale			
Year	Advanced Diesel	Deflator Index	2002 \$
1984	45.0	67.27	72.7
1985	39.8	69.58	62.1
1986	29.0	71.40	44.1
1987	25.2	73.59	37.2
1988	24.0	76.28	34.2
1989	24.7	79.49	33.8
1990	38.6	82.93	50.6
1991	34.9	86.23	44.0
1992	32.8	88.60	40.2
1993	35.1	90.94	41.9
1994	32.4	93.11	37.8
1995	34.4	95.26	39.2
1996	46.1	97.05	51.6
1997	41.6	98.85	45.7
1998	28.8	100.00	31.3
1999	34.2	101.81	36.5
2000	76.7	103.85	80.2
2001		106.23	
2002		108.64	

Average =	46.07	Cents per gallon
Standard Deviation =	13.79	Cents per gallon
Average Plus Standard Deviation =	\$0.599	Dollars per gallon
Average Minus Standard Deviation =	\$0.323	Dollars per gallon
Mimimum =	\$0.313	(2002\$)
Maximum =	\$0.802	(2002\$)

Option 2E--Mature LPG Market--Light-Duty Vehicles

INPUTS

Fleet Information	Units	LPG Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1,000	Vehicles	1,000
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gallon	15.8	Miles/Gallon	21.2
Fuel Consumption	Gallons/Year	791,139	Gallons/Year	589,623
Daily Consumption	Gallons/weekday	2,536	Gallons/weekday	1,890

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	LPG Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$2,900	\$200	\$0	\$0
Total Incremental Vehicle Cost	\$	\$2,900,000	\$200,000	\$0	\$0

Fuel Costs	Units	LPG		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.31	\$1.01	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$1,033,587	\$798,546	\$1,067,217	\$866,745

OUTPUTS

LPG Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (LPG-Gasoline)	Incremental Annual Fuel Cost (LPG-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$200,000	-\$268,671	-\$1,874,604	\$149,900	\$149,900	-\$0.293	\$0.025
High	Low	\$2,900,000	\$166,842	\$4,188,307	\$149,900	\$4,338,207	\$0.736	\$0.736
Low	Low	\$200,000	-\$68,199	-\$326,615	\$149,900	\$149,900	-\$0.030	\$0.025
High	High	\$2,900,000	-\$33,630	\$2,640,317	\$149,900	\$2,790,217	\$0.473	\$0.473

(Note: Assumes all "+" Consumer Costs are paid by Government)

LPG Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (LPG-Gasoline)	Incremental Annual Fuel Cost (LPG-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$200	-\$269	-\$1,875	\$150	\$150	-\$1,725
High	Low	\$2,900	\$167	\$4,188	\$150	\$4,338	\$4,338
Low	Low	\$200	-\$68	-\$327	\$150	\$150	-\$177
High	High	\$2,900	-\$34	\$2,640	\$150	\$2,790	\$2,790

("-" represents savings to user; no government cost)

## Option 2E--Mature LPG Market--Light-Duty Vehicles

### INPUTS

	Unit	
<b>Fleet Information</b>		
Number of Vehicles		1,000
Fuel Consumption	<b>Gallons/Year</b>	791,139
Daily Consumption	<b>Gallons/weekday</b>	2,536

<b>Station Owner Information</b>		
ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

<b>Capital Costs</b>		
Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$100,000
Station Upgrade Expenses (total)	<b>\$</b>	\$100,000

<b>Other Costs</b>		
Revenue from Retail Mark-Up	<b>\$/year</b>	\$118,671 (assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.15
Gulf Coast to CA LPG Annual Import Cost	<b>\$/year</b>	\$159,038 (assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	Fuel Cost to Station Owner	Target Return on Capital	Annual Fuel Cost	Target Revenue from Fuel Sales	Target Fuel Price without Taxes	Fuel Price with Taxes
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low LPG Wholesale Cost	\$0.32	\$13,388	\$533,102	\$546,490	\$0.69	\$1.01
High LPG Wholesale Cost	\$0.60	\$13,388	\$751,237	\$764,625	\$0.97	\$1.31

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	<b>LPG</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	83,572	112,000	126,000
CA Taxes =	\$0.060	\$0.18	\$0.24
Fed Taxes =	\$0.186	\$0.18	\$0.18
Total Exise Taxes =	\$0.246	\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

cents/gallon			
Annual			
W'sale			
Year	Advanced Diesel	Deflator Index	2002 \$
1984	45.0	67.27	72.7
1985	39.8	69.58	62.1
1986	29.0	71.40	44.1
1987	25.2	73.59	37.2
1988	24.0	76.28	34.2
1989	24.7	79.49	33.8
1990	38.6	82.93	50.6
1991	34.9	86.23	44.0
1992	32.8	88.60	40.2
1993	35.1	90.94	41.9
1994	32.4	93.11	37.8
1995	34.4	95.26	39.2
1996	46.1	97.05	51.6
1997	41.6	98.85	45.7
1998	28.8	100.00	31.3
1999	34.2	101.81	36.5
2000	76.7	103.85	80.2
2001		106.23	
2002		108.64	

Average =	46.07	Cents per gallon
Standard Deviation =	13.79	Cents per gallon
Average Plus Standard Deviation =	\$0.599	Dollars per gallon
Average Minus Standard Deviation =	\$0.323	Dollars per gallon
Mimimum =	\$0.313	(2002\$)
Maximum =	\$0.802	(2002\$)

## **Option 2F**

### **Alcohol Fuels in Flexible Fuel Vehicles**

**(Analysis by Tom MacDonald & Mike McCormack)**

#### **Description**

This strategy would involve a range of state and federal actions as well as actions by private fuel suppliers and automobile companies to significantly expand the use of alcohol fuels in flexible fuel vehicles (FFVs).

#### **Background**

FFVs are capable of fueling with alcohol fuels (ethanol or methanol) in any combination with gasoline. Increasing introduction of FFVs in the vehicle population coupled with the necessary alcohol fuel supply and fueling infrastructure offers California a means of reducing its future dependence on gasoline.

The current auto industry production of FFVs is being stimulated by Corporate Average Fuel Economy (CAFE) credits originally enacted in 1988. Manufacturers are entitled to a credit against their mandated average fuel economy for all vehicle sales for sales of FFVs. A maximum credit (or CAFE average addition) of 1.2 miles per gallon is allowable for any manufacturer, a “cap” that is statutorily scheduled to diminish to 0.9 miles per gallon as of the 2004 model year. While the FFV production levels equating with the above caps cannot be precisely calculated, a general estimate is that most manufacturers would reach the cap with production of 7 to 10 percent of their entire U.S. sales volume as FFVs. To date, only the “Big Three” U.S. auto makers have marketed FFV models, with the foreign-based companies not in a CAFE-constrained position that would lead them to take advantage of the credits for FFV production.

The current FFV inroads resulting from CAFE credits adopted in the Alternative Motor Fuels Act of 1988 had led to a significant number of E-85 capable vehicles, but this trend cannot be considered adequate assurance of a substantial future FFV population. This outcome will require a commitment to expanded, sustained FFV production by the worldwide auto industry, most likely supported by government financial and regulatory inducements well beyond the CAFE credits. Establishing the necessary fuel supplies and fueling infrastructure to make the use of alternative fuels in these vehicles practical and affordable will require further initiatives and investments by the fuel supply industry, also likely to require government inducement.

#### **Assumptions and Methodology**

While the outlook for FFV production and fueling is subject to open-ended speculation, three different scenarios extending through the year 2030 examined as part of this analysis include:

- FFV sales reach and maintain levels that capture maximum available CAFE credits for U.S. manufacturers. We will examine this case in our Intermediate Market evaluation.

- FFVs become 10 percent of the state's light-duty vehicle population by 2020 and 30 percent by 2030. We will examine this case in our Mature Market evaluation.
- a "maximum achievable" scenario in which all new light-duty vehicles sold in the state become FFVs by 2017. We will examine this case in our Ultimate Market evaluation.

The current California FFV population and annual sales trend was developed by the Energy Commission's Transportation Fuel Supply and Demand Office based on analysis of Department of Motor Vehicles registration records. These records of gasoline and FFV ownership patterns were used to construct the three future scenarios.

For all three scenarios, the potential gasoline displacement effect of the resulting FFV populations was estimated by assuming all FFVs are fueled entirely with fuels consisting of 85 percent ethanol or methanol, with 15 percent gasoline. FFVs fueled with E-85 are assumed to get 16.2 miles per gallon of E-85, while the average light-duty vehicles they would displace are assumed to get 21.2 miles per gallon of gasoline. Gasoline displacement potential for these three scenarios is estimated.

### **Status of Flexible Fuel Vehicles**

All of the "Big Three" U.S. automobile manufacturers are currently building some models as standard production FFV models. California's vehicle population now includes an estimated 120,000 ethanol FFVs produced in the 1997 through 2002 model years. About 40,000 new ethanol FFVs per year are being sold, representing about 2 percent of the state's new vehicle market.

All FFV models currently being produced are designed for use of ethanol in any combination with gasoline, up to 85 percent ethanol (E85). In past model years, FFVs designed for use of methanol and gasoline (up to M85) have also been produced and sold in California, with approximately 8,000 of these methanol FFVs estimated to still be in operation. While commercial FFV production to date has been limited to the Big Three U.S. manufacturers, eight other auto companies, including most of the major Asian and European auto makers, have provided pre-commercial FFV models for past California demonstration programs. Thus, the industry-wide technological capability for expanded FFV production appears well within reach.

Furthermore, some FFV demonstration models have been built with both ethanol and methanol fueling capability, providing evidence that future FFV models could be produced that could use either of these alcohol fuels, or even combinations of the two with gasoline. Other possible fuels for FFVs may also be developed. The "P-Series" fuel recently licensed to Pure Energy Corporation for commercial production and distribution provides one example. This fuel uses a combination of ethanol, co-solvents (potentially derived from waste biomass resources), natural gas liquids and refinery pentanes (a rejected blendstock when making ethanol-containing CaRFG). This is an EPACT designated alternative fuel that, by definition, is substantially non-petroleum.

## Results

**Intermediate Market.** In an intermediate market, FFV production by the “Big Three” auto makers is assumed to increase, by the 2005 model year, to the level at which full advantage of the existing CAFE credits is captured, assumed to be 8 percent of these companies’ national and California light-duty vehicle markets. This level of FFV introduction is maintained throughout the period, with annual FFV sales in the state ultimately reaching about 130,000 vehicles per year and the cumulative FFV population reaching 1.6 million vehicles (by 2030). Life cycle cost results are shown below for the intermediate market. Fuel costs are the primary cost element, and they are based upon a range of recent historical data.

**Table 2F-1. Intermediate and Mature E-85 FFV Market**

FFVs	Gasoline ICE Vehicles	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	0	221	1,704	0.25	0.25
Low	Low	0	421	3,252	0.51	0.51
High	High	200	537	4,343	0.70	0.70
High	Low	200	737	5,891	0.96	0.96

Gasoline displaced by E-85 vehicles is based on an assumption that they will use E-85 whenever they refuel. These vehicles are capable of using gasoline if the operator cannot locate an E-85 station, so the gasoline displacement levels reported below are upper limits.

**Table 2F-2. Intermediate E-85 FFV Market**

Maximum CAFE Credits	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)	360	650	870
Reduction From Base Case Demand (percent)	2.1	3.3	3.9

**Mature Market.** In a mature market, FFV production is assumed to further expand industry-wide to levels that result in 10 percent of the state’s vehicle population comprised of FFVs by 2020, or about 3 million of the 30 million vehicles projected to be in use by that year. By 2030, this scenario is increased to a 30 percent FFV population, with FFVs accounting for 11 million of the state’s projected 36 million vehicles.

As stated above, gasoline displaced by E-85 vehicles is based on an assumption that they will use E-85 whenever they refuel. These vehicles are capable of using gasoline if the operator cannot locate an E-85 station, so the gasoline displacement levels reported below are upper limits.

**Table 2F-3. Mature E-85 FFV Market**

10% Market by 2020; 30% by 2030	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)	720	1,460	5,710
Reduction From Base Case Demand (percent)	4.3	8.5	25

**Ultimate Market.** In this option, we also include an ultimate market, where FFV production is assumed to reach a “maximum achievable” level and all new light-duty vehicles produced for the California market are FFVs by 2017 and beyond. By 2030, this results in an FFV population comprising 33.6 million (or about 93 percent) of the state’s projected 36 million light-duty vehicles.

As stated above, gasoline displaced by E-85 vehicles is based on an assumption that they will use E-85 whenever they refuel. These vehicles are capable of using gasoline if the operator cannot locate an E-85 station, so the gasoline displacement levels reported below are upper limits.

**Table 2F-4. Ultimate E-85 FFV Market**

<b>Maximum Achievable</b>	<b>Annual Gasoline Reduction</b>		
	<b>2010</b>	<b>2020</b>	<b>2030</b>
Strategy Results (millions of gallons)	1,380	9,760	18,200
Reduction From Base Case Demand (percent)	8.1	50	81

**Ethanol Availability.** Appendix B, titled “Ethanol Demand and Supply Analysis” discusses the availability of ethanol to meet the demand levels implied by this option and Option 2G. Based upon the analysis included in Appendix B, there appears to be sufficient ethanol from a combination of in-state production, 49-state production and foreign production to meet the intermediate market ethanol demand, and about one-half of the ultimate market ethanol demand. However, both of these levels of demand would require significant new production capacity.

### **Key Drivers and Uncertainties**

Major factors that will determine the actual potential for FFVs to displace petroleum in California are:

1. Availability of E-85 fuel at prices sufficiently below gasoline to cause owners to seek out and use E-85 refueling facilities rather than the generally more available gasoline refueling facilities.
2. The federal government’s action regarding continuing, revising or rescinding the CAFE credit for production of FFVs.
3. Possible emergence of other stimuli that may foster increased auto industry FFV production, including FFV offerings by foreign manufacturers and overall industry production at market penetration levels beyond those induced by the CAFE credits.
4. FFV marketing decisions specific to California, including manufacturers electing to pursue emission certification and California marketing of all FFV models; also, the extent to which state and federal air quality regulatory approaches support (or accommodate) FFVs.
5. The extent to which the above factors combine to produce a sufficient “critical mass” FFV population in the state to warrant necessary investments in fueling infrastructure.

6. The extent to which large fleet owners of FFVs (including both private fleets and publicly owned fleets such as the state government fleet) elect to lead the way by establishing E85 fueling.
7. Progress in the development of processes and projects for producing alcohol fuels, in-state, nationally and internationally
8. The comparative market economics of ethanol and gasoline, as affected by government incentives and tax policies, including possible revision to the current federal tax incentives which provide greater market impetus for ethanol/gasoline blending than for E85 distribution.

Option 2F--Intermediate E-85 FFV Market

INPUTS

Fleet Information	Units	E-85 Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1	Vehicles	1
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gallon	16.2	Miles/Gallon	21.2
Fuel Consumption	Gallons/Year	772	Gallons/Year	590
Daily Consumption	Gallons/weekday	2	Gallons/weekday	2

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	E-85 Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$200	\$0	\$0	\$0
Total Incremental Vehicle Cost	\$	\$200	\$0	\$0	\$0

Fuel Costs	Units	E-85		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$2.078	\$1.669	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$1,604	\$1,288	\$1,067	\$867

OUTPUTS

E-85 Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (E-85-Gasoline)	Incremental Annual Fuel Cost (E-85-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$0	\$221	\$1,704	-\$248	\$1,456	\$0.247	\$0.247
High	Low	\$200	\$737	\$5,891	-\$248	\$5,643	\$0.957	\$0.957
Low	Low	\$0	\$421	\$3,252	-\$248	\$3,004	\$0.509	\$0.509
High	High	\$200	\$537	\$4,343	-\$248	\$4,095	\$0.695	\$0.695

(Note: Assumes all "+" Consumer Costs are paid by Government)

E-85 Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (E-85-Gasoline)	Incremental Annual Fuel Cost (E-85-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$0	\$221	\$1,704	-\$248	\$1,456	\$1,456
High	Low	\$200	\$737	\$5,891	-\$248	\$5,643	\$5,643
Low	Low	\$0	\$421	\$3,252	-\$248	\$3,004	\$3,004
High	High	\$200	\$537	\$4,343	-\$248	\$4,095	\$4,095

("-" represents savings to user; no government cost)

## Option 2F-- Intermediate E-85 FFV Market

### INPUTS

		Unit
Fleet Information		
Number of Vehicles		1
Fuel Consumption	Gallons/Year	772
Daily Consumption	Gallons/weekday	2

<b>Station Owner Information</b>		
ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

<b>Capital Costs</b>		
Number of Stations	<b>each</b>	0
Station Upgrade cost (each)	<b>Dollars</b>	\$50,000
Station Upgrade Expenses (total)	<b>\$</b>	\$0

<b>Other Costs</b>		
Revenue From Reteail Mark=Up	<b>\$/year</b>	\$116
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00
Gulf Coast to CA Annual Import Cost	<b>\$/year</b>	\$0

(assume same retail mark-up per gallon as gasoline, \$0.15/gallon)

(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low E-85 Wholesale Cost	\$1.080	\$0	\$949	\$949	\$1.23	\$1.669
High E-85 Wholesale Cost	\$1.460	\$0	\$1,242	\$1,242	\$1.61	\$2.078

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	<b>E-85</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	80,550	112,000	126,000
CA Taxes =	\$0.190	\$0.18	\$0.24
Fed Taxes =	\$0.129	\$0.18	\$0.18
Total Exise Taxes =	\$0.319	\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

Option 2F--Mature E-85 FFV Market

INPUTS

Fleet Information	Units	E-85 Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1	Vehicles	1
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gallon	16.2	Miles/Gallon	21.2
Fuel Consumption	Gallons/Year	772	Gallons/Year	590
Daily Consumption	Gallons/weekday	2	Gallons/weekday	2

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	E-85 Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$200	\$0	\$0	\$0
Total Incremental Vehicle Cost	\$	\$200	\$0	\$0	\$0

Fuel Costs	Units	E-85		Gasoline	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$2.078	\$1.669	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$1,604	\$1,288	\$1,067	\$867

OUTPUTS

E-85 Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (E-85-Gasoline)	Incremental Annual Fuel Cost (E-85-Gasoline)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$0	\$221	\$1,704	-\$248	\$1,456	\$0.247	\$0.247
High	Low	\$200	\$737	\$5,891	-\$248	\$5,643	\$0.957	\$0.957
Low	Low	\$0	\$421	\$3,252	-\$248	\$3,004	\$0.509	\$0.509
High	High	\$200	\$537	\$4,343	-\$248	\$4,095	\$0.695	\$0.695

(Note: Assumes all "+" Consumer Costs are paid by Government)

E-85 Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (E-85-Gasoline)	Incremental Annual Fuel Cost (E-85-Gasoline)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$0	\$221	\$1,704	-\$248	\$1,456	\$1,456
High	Low	\$200	\$737	\$5,891	-\$248	\$5,643	\$5,643
Low	Low	\$0	\$421	\$3,252	-\$248	\$3,004	\$3,004
High	High	\$200	\$537	\$4,343	-\$248	\$4,095	\$4,095

("-" represents savings to user; no government cost)

## Option 2F--Mature E-85 FFV Market

### INPUTS

	Unit	
<b>Fleet Information</b>		
Number of Vehicles		1
Fuel Consumption	Gallons/Year	772
Daily Consumption	Gallons/weekday	2

<b>Station Owner Information</b>		
ROI	%	12%
Investment Life	Year	20

<b>Capital Costs</b>		
Number of Stations	each	0
Station Upgrade cost (each)	Dollars	\$50,000
Station Upgrade Expenses (total)	\$	\$0

Other Costs			
Revenue From Retail Mark-Up	<b>\$/year</b>	\$116	(assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00	
Gulf Coast to CA Annual Import Cost	<b>\$/year</b>	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	Fuel Cost to Station Owner	Target Return on Capital	Annual Fuel Cost	Target Revenue from Fuel Sales	Target Fuel Price without Taxes	Fuel Price with Taxes
	\$/gallon	\$/year	\$/year	\$	\$/gal	\$/gal
Low E-85 Wholesale Cost	\$1.080	\$0	\$949	\$949	\$1.230	\$1.669
High E-85 Wholesale Cost	\$1.460	\$0	\$1,242	\$1,242	\$1.610	\$2.078

	E-85	Gasoline	Diesel
LHV Energy Content =	80,550	112,000	126,000
CA Taxes =	\$0.190	\$0.18	\$0.24
Fed Taxes =	\$0.129	\$0.18	\$0.18
Total Exise Taxes =	\$0.319	\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

## **Option 2G**

### **Use of Ethanol as a Gasoline Blend**

**(Analysis by Mike McCormack)**

#### **Description**

This option addresses the use of ethanol in California, Phase III reformulated gasoline (CaRFG3). Under current regulations, refiners blend up to 5.7 percent ethanol by volume into gasoline as a substitute for Methyl Tertiary Butyl Ether (MTBE).

#### **Background**

The option of 10 percent ethanol in gasoline is desirable from a petroleum displacement perspective, since an additional 4 percent ethanol by volume could be blended into the gasoline pool. It is presumed that refinery economics are favorable and that emissions benefits of currently envisioned CaRFG3 at 5.7 volume percent ethanol are retained.

Currently, clean fuel specifications require refiners to use a minimum of 5.7 percent by volume of an oxygenate in gasoline blend stock to meet prescribed specifications. To ensure compliance after switching to ethanol, refiners indicate they would actually use about 6.0 percent ethanol to avoid violating the minimum content requirement. Likewise, under current rules refiners are allowed to use no more than 10 percent oxygenate by volume. To avoid exceeding this maximum volume requirement, refiners are expected to use no more than about 9.8 percent ethanol. Thus, increasing ethanol content to the maximum allowable would displace about 3.8 percent gasoline.

In this option, the term “5.7 percent ethanol” represents the expected practice of blending the minimum amount of ethanol required to meet clean fuel regulations, with a small tolerance, as described above. The term “10 percent ethanol” represents the expected practice of blending the maximum amount of ethanol allowed.

Blending greater volumes of ethanol, up to a maximum of 10 percent ethanol by volume, is allowable under the Air Resources Board’s Predictive Model, but is expected to be more expensive than using 5.7 percent ethanol in gasoline. It would require changes in some fuel properties to offset emissions impacts associated with higher oxygen levels, in order to comply with the current emission performance specifications. This may be problematical for some refiners because it could decrease the amount of complying fuel they produce.

Current data on existing vehicle classes in the Air Resources Board’s predictive model show that 10 percent ethanol blends would cause an increase of Oxides of Nitrogen (NO<sub>x</sub>), when compared to blends using 5.7 percent ethanol. In the existing Predictive Model, adding oxygen to fuel tends to decrease carbon monoxide and hydrocarbon emissions but has the undesirable impact of increasing NO<sub>x</sub>. It is possible that these effects could diminish as advanced vehicle technologies are deployed in the fleet. This effect would need to be added to the predictive model and could make it more feasible to use 10 percent ethanol blends.

This analysis is limited to the petroleum reduction and cost impacts of a 10 percent ethanol blend, which might be possible at some future time. For purposes of this evaluation, staff assumed that automobile manufacturers would retain and improve upon fuel systems in passenger cars and light trucks. Cars would need to be designed to drive well and comply with gasoline specifications that allow blends of up to 10 percent ethanol by volume. In addition, manufacturers would need to retain their current warranty policy, which would explicitly allow for up to a 10 percent ethanol blend in gasoline.

For this analysis, staff assumed that the Air Resources Board Predictive Model would be revised by 2010, in order to recognize new emissions data from passenger cars and light trucks, which would characterize then existing vehicle fleet emissions as related to fuel properties. Staff also assumed that adjustments in the Predictive Model would make it easier to offset any increases in hydrocarbon, carbon monoxide, toxic emissions and ozone forming potential by altering fuel properties.

To meet future state evaporative emission requirements for conventional fuels, automobile manufacturers will need to eliminate evaporative and permeation emissions through use of improved fuel system materials, and incorporate emissions and flexible engine/fuel control systems. These systems would allow the use of any level of oxygen in the fuel up to at least 10 percent ethanol content by volume.<sup>1</sup> Thus, for this option, staff assumed zero incremental vehicle capital cost.

### **Status of Fuel Supply**

Regarding ethanol fuel supply to meet this increased demand, staff assumed that new ethanol plants would continue to be built in the United States in response to increased market demand. This demand is expected to increase, with the phase-out of MTBE nationwide and the establishment of a federal renewable fuel standard, if enacted by Congress.

Most of this new production will be located in the U. S. Mid-West and transported to California by marine tanker or barge or by rail. In addition, staff assumed that California's farmers and agricultural interests will establish a base of conventional ethanol production on one million acres of irrigated land now dedicated to crops that provide marginal economic returns and that can be grown elsewhere in the world at lower cost. This conventional ethanol base will be augmented by waste-biomass derived ethanol.

Staff concludes that the growing demand for ethanol can be met with a combination of California ethanol production, importing of ethanol from the Midwest and Pacific Northwest, and foreign imports. These levels of production and imports would meet not only needs for a 10 percent ethanol blending in gasoline, but also the increasing use of ethanol in Flexible Fueled Vehicles (discussed in Option 2F) between now and 2020. The supply analysis for this scenario can be found in Appendix B, titled "Ethanol Supply and Demand Analysis."

### **Assumptions and Methodology**

We estimate the cost to blend gasoline containing 10 percent ethanol to be slightly higher (three to four cents per gallon) than the cost to blend 5.7 percent ethanol in gasoline. Ethanol prices tend to track gasoline prices, and there is a federal tax credit for each volume of ethanol blended into gasoline, which would partially offset the increase in ethanol volume. Staff further assumed that fueling, storage and distribution infrastructure would be in place to serve a 5.7 percent blend market, and would be adequate serve a 10 percent ethanol in gasoline market.

**Intermediate Market.** This result presumes that the logistics of supplying 10 percent by volume ethanol are no greater a challenge than providing the expected 5.7 percent by volume ethanol. It also presumes that sufficient ethanol supply exists, and that the in-state logistics of ethanol transport and dispatching at the terminal rack for supplying 10 percent volume ethanol are accommodated in current planning for use of 5.7 percent ethanol in gasoline.

Because the cost of CaRFG3 and ethanol will be closely tied to one another, we report only results for cases when both ethanol blended fuels are simultaneously low and high.

**Table 2G-1. Intermediate Market with Ten Percent Ethanol in CaRFG3**

10% Ethanol in Gasoline	5.7% Ethanol in Gasoline	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High					
Low	Low	0	15	115	.026	.026
High	High	0	27	211	.042	.042
High	Low					

The following table shows gasoline displaced by using 10 percent ethanol in CaRFG3, rather than 5.7 percent as currently expected. A simple subtraction of the expected increased ethanol volume is 3.8 percent. Adjusting for lower energy content leads to about 3.75 percent gasoline displacement.

**Table 2G-2. Gasoline Displaced With Ten Percent Ethanol in CaRFG3**

	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)	668	760	872
Reduction From Base Case Demand (percent)	3.75	3.75	3.75

**Mature Market.** Assuming sufficient ethanol, and changes in vehicle emissions response allow refiners to produce a specification Phase III, California RFG with 10 percent ethanol and no adverse emissions impacts after 2010, the mature market is identical to the intermediate market.

### Key Drivers and Uncertainties

Major factors that will determine the actual potential for using increased volumes of ethanol to displace gasoline in California are:

1. The availability of sufficient ethanol to serve the increased demand without adversely impacting fuel prices.
2. The willingness of auto manufacturers to continue to develop fuel and emission control systems that will allow operation at 10 percent ethanol in California gasoline, while retaining desirable operating and emissions performance.
3. The adoption of a federal renewable fuel standard, which would assure adequate supplies with minimal price volatility, as the in-state ethanol production industry develops.
4. The assumption that new cars and light truck emission performance will eliminate much of the current emissions penalty associated with 10 percent ethanol in CaRFG3.

---

<sup>1</sup> It should be noted that some auto industry engineers believe that 15 percent ethanol in gasoline in today's new passenger cars and light trucks is a fuel that could provide consumers with driveability indistinguishable from conventional and reformulated gasoline containing lower levels or no ethanol in gasoline. The entire fleet of gasoline vehicles designed by auto manufacturers in Brazil operates on gasoline containing between 22 and 24 percent ethanol. Thus, higher ethanol blend levels are demonstrably real thus suggesting the possibility of more aggressive ethanol-in-gasoline scenarios not included in the present analysis.

Option 2G--10% Ethanol in Gasoline

INPUTS

Fleet Information	Units	E-10 Gasoline Vehicle	Units	Gasoline Vehicle
Number of Vehicles	Vehicles	1	Vehicles	1
Annual Mileage	Miles/Vehicle/Year	12,500	Miles/Vehicle/Year	12,500
Fuel Economy	Miles/Gallon	20.9	Miles/Gallon	21.2
Fuel Consumption	Gallons/Year	598	Gallons/Year	590
Daily Consumption	Gallons/weekday	2	Gallons/weekday	2

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	E-10 Compatible Vehicle		Gasoline Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$0	\$0	\$0	\$0
Total Incremental Vehicle Cost	\$	\$0	\$0	\$0	\$0

Fuel Costs	Units	E-10 in CaRFG		"E-6" CaRFG	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.830	\$1.474	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$1,094	\$882	\$1,067	\$867

(Note: E-10 fuel prices slightly higher to reflect higher ethanol content and price)

OUTPUTS

E-10 Compatible Gasoline Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (E-10 vs Gasoline)	Incremental Annual Fuel Cost (E-10 vs CaRFG)	Present Value Consumer Costs ("Equals Savings")	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$0	-\$186	-\$1,433	\$38	\$38	-\$0.237	\$0.007
High	Low	\$0	\$228	\$1,759	\$38	\$1,797	\$0.305	\$0.305
Low	Low	\$0	\$15	\$115	\$38	\$153	\$0.026	\$0.026
High	High	\$0	\$27	\$211	\$38	\$249	\$0.042	\$0.042

(Note: Assumes all "+" Consumer Costs are paid by Government)

E-10 Compatible Gasoline Vehicle	Gasoline Vehicle	Incremental Annual Vehicle Capital Cost (E-10 vs Gasoline)	Incremental Annual Fuel Cost (E-10 vs CaRFG)	Present Value Consumer Cost Net Present Value ("Equals Savings")	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$0	-\$186	-\$1,433	\$38	\$38	-\$1,395
High	Low	\$0	\$228	\$1,759	\$38	\$1,797	\$1,797
Low	Low	\$0	\$15	\$115	\$38	\$153	\$153
High	High	\$0	\$27	\$211	\$38	\$249	\$249

("-" represents savings to user; no government cost)

## Option 2G--10% Ethanol in Gasoline

### INPUTS

Unit

#### Fleet Information

Number of Vehicles		1
Fuel Consumption	<b>Gallons/Year</b>	598
Daily Consumption	<b>Gallons/weekday</b>	2

#### Station Owner Information

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

#### Capital Costs

Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$0
Station Upgrade Expenses (total)	<b>\$</b>	\$0

#### Other Costs

Station Gasoline Gross Margin	<b>\$/year</b>	\$0	(assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	<b>\$/Gallon</b>	\$0.00	
Gulf Coast to CA Annual Import Cost	<b>\$/year</b>	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

(Note: Fuel Prices calculated on a separate spreadsheet)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low Wholesale Cost	\$0.00	\$0	\$0	\$0	\$0.00	\$0.344
High Wholesale Cost	\$0.00	\$0	\$0	\$0	\$0.00	\$0.344

(taxes only)

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	<b>E-10</b>	<b>E-"6" CaRFG</b>	<b>Diesel</b>
LHV Energy Content =	109,851	111,356	126,000
CA Taxes =	\$0.180	\$0.180	\$0.24
Fed Taxes =	\$0.139	\$0.152	\$0.18
Total Exise Taxes =	\$0.319	\$0.332	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

## **Option 2H**

### **LNG and Advanced NG Engines for Medium- and Heavy Duty Vehicles** **(Analysis by McKinley Addy )**

#### **Description**

This option explores a regulatory or incentive-based strategy intended to increase the use of natural gas in medium- and heavy-duty on road vehicles.

#### **Background**

On-road medium- and heavy-duty vehicles are defined as vehicles weighing greater than 8,500 pounds of gross vehicle weight. Expanded use of alternative fuels in medium-duty and heavy-duty trucks using more efficient, advanced natural gas engine technologies can reduce projected diesel fuel use from this sector. This Option explores the use of compressed natural gas (CNG) in medium-duty vehicles and liquefied natural gas (LNG) or CNG in heavy-duty vehicles. Each would replace a vehicle normally fueled with diesel.

Medium-duty and heavy-duty trucks move much of the nation's goods and are considered vital to the economy. Medium-duty trucks tend to be used in shorter trips with central refueling and hence are more likely to use CNG than LNG. Heavy-duty vehicles are used both for shorter trips and longer trips. They are more suited for LNG than CNG, because LNG has a volumetric energy content closer to diesel than does CNG. Much more diesel fuel is used by heavy-duty vehicles in long trips where central fueling is not an option.

Natural gas medium- and heavy-duty vehicles are an attractive environmental option to diesel fueled vehicles because they emit fewer criteria pollutants and toxic components. However, the limited availability of refueling facilities, and typically higher vehicle purchase prices have affected the sale of this fuel option in these applications.

Staff limited this option to dedicated CNG and LNG vehicles in order to evaluate maximum diesel displacement. Dual fueled and bi-fueled vehicles would cost more to purchase as they have both a diesel and a CNG or LNG fueling system. Since they would use diesel, they would displace less diesel fuel. Furthermore, staff assumed that in a mature market condition, as discussed below, the cost of using natural gas would be significantly less than the cost of using diesel.

#### **Assumptions and Methodology**

Diesel demand reductions in 2010, 2020 and 2030 from on-road heavy-duty vehicles are estimated based on projected sales of natural gas heavy-duty vehicles, associated improvements in advanced natural gas engine fuel economy, existing and projected vehicle populations, infrastructure costs and other assumptions. Key assumptions and common methodology are summarized below.

- Fuel economies and vehicle miles traveled are weighted across vehicle classes.
- All new natural gas vehicles sold by 2020 are fully competitive with conventional diesel vehicles on performance, reliability and durability bases, and meet prevailing emission standards. Compression ignition-based LNG vehicles meet prevailing fuel economy performance of diesel engines. Spark ignition-based CNG engine platforms meet 95 percent of prevailing diesel engine fuel economy performance, due to heavier on-board fuel tanks and throttling losses associated with spark ignition.
- All new vehicles sold replace diesel-fueled vehicles because diesels dominate the vehicle population segment considered.
- Variable penetration rates in all vehicle classes with higher rates in some classes and time periods than others.<sup>1</sup>
- Certain costs are associated with achieving the assumed penetration rates and estimated petroleum displacements for NGVs. These include incremental capital cost, incremental fuel cost, incremental operation and maintenance costs and an incremental infrastructure cost. These costs vary among vehicle classes.

### **Status of Natural Gas Medium and Heavy Duty Vehicles**

Some medium- and heavy-duty trucks use natural gas instead of diesel fuel. A small amount of pilot diesel fuel is used to initiate the combustion. Efforts are under way to limit the amount of pilot diesel fuel needed, and to minimize emissions. Today's economics tend to favor diesel fuel and opportunities to use natural gas are limited. Municipal vehicles, including trash haul applications, street sweepers and utility trucks have all been demonstrated. Heavy-duty applications of natural gas include grocery stores such as Raley's and Von's using CNG, and line-haul trucking such as Harris Ranch with LNG.

Staff determined weighted-averages of the year 2000 vehicle fuel economies for the existing relevant diesel vehicle classes using several sources. In the analysis, staff began with base case vehicles that achieve 12.7 miles per gallon of diesel in Class 3-6 vehicles and 6.5 miles per gallon of diesel in Class 7-8 vehicles.

Natural gas and natural gas vehicle stake holders have joined forces to establish two working groups to advance the state of natural gas heavy-duty vehicles. One is working to improve the vehicles, and the other is working to improve fueling infrastructure.

The U. S. Department of Energy and other stake holders are working jointly to improve the performance of medium-duty and heavy-duty natural gas vehicle technologies.<sup>2</sup> Their near-term objective is to deploy one Class 3-6 by 2004 and one Class 7-8 vehicle by 2007, both of which will be designed to be commercially viable and meet year 2007 emissions targets while significantly advancing the performance capability of natural gas in these applications. Funding needs are \$5 million in 2003 and 2004, decreasing annually to \$1.25 million in 2007. They do

not specifically identify efficiency targets. If funded, they expect that vehicles developed under this program will lead to commercial offerings that will achieve limited market scope with current incentive programs aimed at reducing emissions or displacing petroleum fuels.

Many of the same stakeholders are also involved in improving the refueling infrastructure in an effort to build the market for natural gas vehicles.<sup>3</sup> This effort focuses upon improved gas compression methods and component integration for compressed natural gas (CNG) and lowering the cost of liquefied natural gas (LNG) production by developing small-scale LNG production technology and lower cost equipment. Ensuring safety and reliability are important aspects of this work.

**Intermediate Market.** Not evaluated.

**Mature Market.** In a mature market, staff assumed that R&D successfully reduces incremental capital costs of medium-duty CNG vehicles from a high of \$11,000 in 1997 to \$2,000 by 2030. Staff assumed that R&D successfully reduces incremental capital cost of CNG Class 7-8 heavy-duty vehicles from a high of \$45,000 in 1997 to \$11,000 by 2030. Similarly, the incremental capital cost of LNG Class 7-8 heavy-duty vehicles decreases from \$28,767 in 1997 to \$4,700 by 2030.

Five natural gas infrastructure cost scenarios were evaluated to obtain a natural gas price ranged used in the analysis:

- Infrastructure costs for fleets with medium-duty vehicles only.
- Infrastructure costs for fleets with CNG heavy-duty vehicles only, i.e., transit agencies.
- Infrastructure costs for fleets with LNG heavy-duty vehicles only, i.e., Raley's.
- Infrastructure costs for fleets with a mix of heavy-duty CNG and LNG vehicles only, i.e., municipalities such as the City of Long Beach.
- Infrastructures that serve medium-duty and heavy-duty CNG vehicles, and LNG heavy-duty vehicles. Station developers may opt to build combined liquefied and compressed natural gas refueling facilities. This leads to the lowest infrastructure costs because costs are amortized over a larger number of vehicles.

The results of the economic analysis are as follows:

**Table 2H-1. Mature Market CNG Class 3-6 Medium-Duty Trucks**

NG Trucks	Diesel ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	2,000	-2,915	-29,589	0.07	-0.65
Low	Low	2,000	-2,044	-20,156	0.07	-0.42
High	High	11,000	-2,165	-12,464	0.07	-0.23
High	Low	11,000	-1,295	-3,031	0.07	0

**Table 2H-2. Mature Market CNG Class 7-8 Heavy-Duty Trucks**

NG Trucks	Diesel ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	11,000	-13,322	-133,382	.04	-0.59
Low	Low	11,000	-8,771	-84,062	.04	-0.36
High	High	28,000	-8,566	-64,838	.04	-0.27
High	Low	28,000	-4,015	-15,518	.04	-.04

**Table 2H-3. Mature Market LNG Class 7-8 Heavy-Duty Trucks**

NG Trucks	Diesel ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consumer Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	11,000	-16,863	-171,760	.06	-0.74
Low	Low	11,000	-12,312	-122,439	.06	-0.51
High	High	28,000	-14,611	-130,355	.06	-0.55
High	Low	28,000	-10,061	-81,035	.06	-0.32

Once the mature market develops, the life cycle cost of using natural gas in medium-duty and heavy-duty vehicles provides savings to the operator for each class of truck and whether or not the vehicle uses CNG or LNG. The choice of fuel may depend on refueling needs, as discussed above, with CNG likely to be used in centrally fueled vehicles and LNG in long haul vehicles. The availability of LNG may also be a factor, unless a LNG terminal is built in California.

The \$0.04 to 0.07 per gallon costs to government are associated with reduced excise tax collection.

**Diesel Displacement.** The amount of diesel displaced by this option is shown below. The number of Class 3-6 and Class 7-8 vehicles operating on California roadways using natural gas under a mature market is also shown. Data are for total fuel displaced, based upon in-state diesel fuel purchases.

**Table 2H-4. Diesel Displaced by Natural Gas Medium and Heavy-Duty Vehicles**

	Annual Diesel Reduction		
	2010	2020	2030
Annual Reduction in Diesel Consumption (million gallons)	17	60	970
Class 3-6 Vehicles operating in year indicated	7,350	27,500	66,000
Class 7-8 Vehicles operating in year indicated	9,800	32,000	78,000
Reduction From Base Case Demand (Percent)	4	10	20

### Key Drivers and Uncertainties

1. Assuming fuel economy of natural gas vehicles approaches that of diesel fueled vehicles.

2. Assuming NGVs are as fuel efficient as corresponding diesel vehicles.
3. Assuming Vehicle class distribution does not change.
4. Assuming vehicle miles traveled are the same for diesel and natural gas vehicles (affects demand reduction and incremental operating costs).
5. Assuming a more rapid fleet turnover in the years 2015-2030 as vehicle fleet ages and replacement is justified by lower operating cost from more fuel-efficient vehicles.

---

<sup>1</sup> As used in this analysis, vehicle penetration rate means a percentage of new vehicles entering the existing fleet population. For this scenario, 100 percent of new vehicles sold meet the assumed fuel economy targets used in the analysis. It is estimated that new vehicle sales are fewer than 10 percent of the existing population in any given year. The penetration rate is varied to reflect rapid turnover of the vehicle population. A higher penetration rate is assumed to occur in the years 2015-2030 from aging and the availability of more fuel-efficient vehicles. A composite vehicle class distribution is used in estimating the vehicle penetrations.

<sup>2</sup> Next-Generation Natural Gas Vehicle Program, Vehicle Working Group Workshop and Meeting, October, 2001.

<sup>3</sup> Natural Gas Vehicle Infrastructure Working Group and Vehicle Working Group, Summary of Recommendations to Overcome Natural Gas Vehicle Infrastructure Technology Obstacles, September 2001.

Option 2H--Class 3-6 CNG Trucks with Advanced Natural Gas Engines--Mature Market

INPUTS

Fleet Information	Units	CNG Vehicle	Units	Diesel Vehicle
Number of Vehicles	Vehicles	196,800	Vehicles	196,800
Annual Mileage (diesel equiv.)	Miles/Vehicle/Year	32,000	Miles/Vehicle/Year	32,000
Fuel Economy (diesel equiv.)	Miles/Gallon	17.5	Miles/Gallon	12.5
Fuel Consumption (diesel eq.)	Gallons/Year	359,862,857	Gallons/Year	503,808,000
Daily Consumption (diesel eq.)	Gallons/weekday	1,153,407	Gallons/weekday	1,614,769

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	16

Vehicle Capital Costs	Units	CNG Vehicle		Diesel Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$11,000	\$2,000	\$0	\$0
Total Incremental Vehicle Cost	\$	\$2,164,800,000	\$393,600,000	\$0	\$0

Fuel Costs	Units	CNG		Diesel	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$GDE & \$/gal	\$1.35	\$0.94	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$485,814,857	\$338,271,086	\$911,892,480	\$740,597,760

OUTPUTS

CNG Vehicle	Diesel Vehicle	Incremental Annual Vehicle Capital Cost (CNG-Diesel)	Incremental Annual Fuel Cost (CNG-Diesel)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$393,600,000	-\$573,621,394	-\$5,823,176,486	\$577,996,409	\$577,996,409	-\$0.651	\$0.072
High	Low	\$2,164,800,000	-\$254,782,903	-\$596,478,389	\$577,996,409	\$577,996,409	-\$0.002	\$0.072
Low	Low	\$393,600,000	-\$402,326,674	-\$3,966,723,784	\$577,996,409	\$577,996,409	-\$0.420	\$0.072
High	High	\$2,164,800,000	-\$426,077,623	-\$2,452,931,091	\$577,996,409	\$577,996,409	-\$0.233	\$0.072

(Note: Assumes all "+" Consumer Costs paid by Government)

CNG Vehicle	Diesel Vehicle	Incremental Annual Vehicle Capital Cost (CNG-Diesel)	Incremental Annual Fuel Cost (CNG-Diesel)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$2,000	-\$2,915	-\$29,589	\$2,937	\$2,937	-\$26,652
High	Low	\$11,000	-\$1,295	-\$3,031	\$2,937	\$2,937	-\$94
Low	Low	\$2,000	-\$2,044	-\$20,156	\$2,937	\$2,937	-\$17,219
High	High	\$11,000	-\$2,165	-\$12,464	\$2,937	\$2,937	-\$9,527

("-" represents savings to user; no government cost)

## Option 2H--Class 3-6 CNG Trucks with Advanced Natural Gas Engines

### INPUTS

Unit

#### Fleet Information

Number of Vehicles		196,800
Fuel Consumption	<b>GDE/Year</b>	359,862,857
Daily Consumption	<b>GDE/weekday</b>	1,153,407

#### Station Owner Information

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

#### Capital Costs

Number of Stations	<b>each</b>	0
Station Upgrade cost (each)	<b>Dollars</b>	\$100,000
Station Upgrade Expenses (total)	<b>\$</b>	\$0

#### Other Costs

Revenue from Retail Mark-Up	<b>\$/year</b>	\$0	(assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
Gulf Coast to CA Gasoline Import Fee	<b>\$/GDE</b>	\$0.00	
Gulf Coast to CA CNG Annual Import Cost	<b>\$/year</b>	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/GDE</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/GDE</b>	<b>\$/GDE</b>
Low Wholesale Cost	\$0.49	\$0	\$176,332,800	\$176,332,800	\$0.94	\$0.94
High Wholesale Cost	\$0.71	\$0	\$255,502,629	\$255,502,629	\$1.35	\$1.35

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	<b>CNG</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	33,000	112,000	126,000
CA Taxes =	\$0.000	\$0.18	\$0.24
Fed Taxes =	\$0.000	\$0.18	\$0.18
Total Exise Taxes =	\$0.360	\$0.36	\$0.42
Sales Taxes =	0.00%	7.75%	7.75%

cents/gallon			
Annual			
W'sale			
Year	Advanced Diesel	Deflator Index	2002 \$
1984	45.0	67.27	72.7
1985	39.8	69.58	62.1
1986	29.0	71.40	44.1
1987	25.2	73.59	37.2
1988	24.0	76.28	34.2
1989	24.7	79.49	33.8
1990	38.6	82.93	50.6
1991	34.9	86.23	44.0
1992	32.8	88.60	40.2
1993	35.1	90.94	41.9
1994	32.4	93.11	37.8
1995	34.4	95.26	39.2
1996	46.1	97.05	51.6
1997	41.6	98.85	45.7
1998	28.8	100.00	31.3
1999	34.2	101.81	36.5
2000	76.7	103.85	80.2
2001		106.23	
2002		108.64	

<u>Diesel Equivalents</u>			
Average =	46.07	Cents per gallon	
Standard Deviation =	13.79	Cents per gallon	
Average Plus Standard Deviation =	\$0.710	Dollars per gallon	
Average Minus Standard Deviation =	\$0.490	Dollars per gallon	
Mimimum =	\$0.313	(2002\$)	
Maximum =	\$0.802	(2002\$)	

Option 2H--Class 7-8 CNG Trucks with Advanced Natural Gas Engines--Mature Market

INPUTS

Fleet Information	Units	CNG Vehicle	Units	Diesel Vehicle
Number of Vehicles	Vehicles	177,800	Vehicles	177,800
Annual Mileage (diesel equiv.)	Miles/Vehicle/Year	87,000	Miles/Vehicle/Year	87,000
Fuel Economy (diesel equiv.)	Miles/GDE	7.5	Miles/Gallon	6.5
Fuel Consumption (diesel eq.)	GDE/Year	2,062,480,000	Gallons/Year	2,379,784,615
Daily Consumption (diesel eq.)	GDE/weekday	6,610,513	Gallons/weekday	7,627,515

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	16

Vehicle Capital Costs	Units	CNG Vehicle		Diesel Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$28,000	\$11,000	\$0	\$0
Total Incremental Vehicle Cost	\$	\$4,978,400,000	\$1,955,800,000	\$0	\$0

Fuel Costs	Units	CNG		Diesel	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/GDE & \$/gal	\$1.35	\$0.94	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$2,784,348,000	\$1,938,731,200	\$4,307,410,154	\$3,498,283,385

OUTPUTS

CNG Vehicle	Diesel Vehicle	Incremental Annual Vehicle Capital Cost (CNG-Diesel)	Incremental Annual Fuel Cost (CNG-Diesel)	Present Value Consumer Costs (" " Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$1,955,800,000	-\$2,368,678,954	-\$23,715,396,664	\$1,315,369,420	\$1,315,369,420	-\$0.59	\$0.035
High	Low	\$4,978,400,000	-\$713,935,385	-\$2,759,067,179	\$1,315,369,420	\$1,315,369,420	-\$0.04	\$0.035
Low	Low	\$1,955,800,000	-\$1,559,552,185	-\$14,946,267,194	\$1,315,369,420	\$1,315,369,420	-\$0.358	\$0.035
High	High	\$4,978,400,000	-\$1,523,062,154	-\$11,528,196,649	\$1,315,369,420	\$1,315,369,420	-\$0.268	\$0.035

(Note: Assumes all "+" Consumer Costs paid by Government)

CNG Vehicle	Diesel Vehicle	Incremental Annual Vehicle Capital Cost (CNG-Diesel)	Incremental Annual Fuel Cost (CNG-Diesel)	Present Value Consumer Cost Net Present Value (" " Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$11,000	-\$13,322	-\$133,382	\$7,398	\$7,398	-\$125,984
High	Low	\$28,000	-\$4,015	-\$15,518	\$7,398	\$7,398	-\$8,120
Low	Low	\$11,000	-\$8,771	-\$84,062	\$7,398	\$7,398	-\$76,664
High	High	\$28,000	-\$8,566	-\$64,838	\$7,398	\$7,398	-\$57,440

("-" represents savings to user; no government cost)



cents/gallon			
Annual			
W'sale			
Year	Advanced Diesel	Deflator Index	2002 \$
1984	45.0	67.27	72.7
1985	39.8	69.58	62.1
1986	29.0	71.40	44.1
1987	25.2	73.59	37.2
1988	24.0	76.28	34.2
1989	24.7	79.49	33.8
1990	38.6	82.93	50.6
1991	34.9	86.23	44.0
1992	32.8	88.60	40.2
1993	35.1	90.94	41.9
1994	32.4	93.11	37.8
1995	34.4	95.26	39.2
1996	46.1	97.05	51.6
1997	41.6	98.85	45.7
1998	28.8	100.00	31.3
1999	34.2	101.81	36.5
2000	76.7	103.85	80.2
2001		106.23	
2002		108.64	

Average =	46.07	Cents per gallon
Standard Deviation =	13.79	Cents per gallon
Average Plus Standard Deviation =	\$0.710	Dollars per gallon
Average Minus Standard Deviation =	\$0.490	Dollars per gallon
Mimimum =	\$0.313	(2002\$)
Maximum =	\$0.802	(2002\$)

Option 2H--Class 7-8 LNG Trucks with Advanced Natural Gas Engines--Mature Market

INPUTS

Fleet Information	Units	LNG Vehicle	Units	Diesel Vehicle
Number of Vehicles	Vehicles	177,800	Vehicles	177,800
Annual Mileage (diesel equiv.)	Miles/Vehicle/Year	87,000	Miles/Vehicle/Year	87,000
Fuel Economy (diesel equiv.)	Miles/Gallon	8.5	Miles/Gallon	6.5
Fuel Consumption (diesel eq.)	Gallons/Year	1,819,835,294	Gallons/Year	2,379,784,615
Daily Consumption (diesel eq.)	Gallons/weekday	5,832,805	Gallons/weekday	7,627,515

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	16

Vehicle Capital Costs	Units	LNG Vehicle		Diesel Vehicle	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$28,000	\$11,000	\$0	\$0
Total Incremental Vehicle Cost	\$	\$4,978,400,000	\$1,955,800,000	\$0	\$0

Fuel Costs	Units	LNG		Diesel	
		Mean Price + One Standard Deviation	Mean Price - One Standard Deviation	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/GDE	\$0.94	\$0.72	\$1.81	\$1.47
Annual Fuel Cost	\$/year	\$1,709,495,010	\$1,309,131,245	\$4,307,410,154	\$3,498,283,385

OUTPUTS

LNG Vehicle	Diesel Vehicle	Incremental Annual Vehicle Capital Cost (LNG-Diesel)	Incremental Annual Fuel Cost (LNG-Diesel)	Present Value Consumer Costs (" Equals Savings)	Present Value Change in Excise Taxes	Present Value Cost To Government	Present Value Total \$/Gallon Displaced	Present Value Government Cost \$/Gallon Displaced
Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
Low	High	\$1,955,800,000	-\$2,998,278,909	-\$30,538,855,889	\$2,262,071,287	\$2,262,071,287	-\$0.743	\$0.059
High	Low	\$4,978,400,000	-\$1,788,788,375	-\$14,408,076,197	\$2,262,071,287	\$2,262,071,287	-\$0.319	\$0.059
Low	Low	\$1,955,800,000	-\$2,189,152,139	-\$21,769,726,419	\$2,262,071,287	\$2,262,071,287	-\$0.512	\$0.059
High	High	\$4,978,400,000	-\$2,597,915,144	-\$23,177,205,667	\$2,262,071,287	\$2,262,071,287	-\$0.549	\$0.059

(Note: Assumes all "+" Consumer Costs paid by Government)

LNG Vehicle	Diesel Vehicle	Incremental Annual Vehicle Capital Cost (LNG-Diesel)	Incremental Annual Fuel Cost (LNG-Diesel)	Present Value Consumer Cost Net Present Value (" Equals Savings)	Present Value Per Vehicle Change in Excise Taxes	Present Value Per Vehicle Cost To Government	Net Cost Per Vehicle
Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low	High	\$11,000	-\$16,863	-\$171,760	\$12,723	\$12,723	-\$159,037
High	Low	\$28,000	-\$10,061	-\$81,035	\$12,723	\$12,723	-\$68,313
Low	Low	\$11,000	-\$12,312	-\$122,439	\$12,723	\$12,723	-\$109,717
High	High	\$28,000	-\$14,611	-\$130,355	\$12,723	\$12,723	-\$117,633

("-" represents savings to user; no government cost)

## Option 2H--Class 7-8 LNG Trucks with Advanced Natural Gas Engines

### INPUTS

#### Unit

#### Fleet Information

Number of Vehicles		177,800
Fuel Consumption (Diesel Equivalent)	<b>GDE/Year</b>	1,819,835,294
Daily Consumption (Diesel Equivalent)	<b>GDE/weekday</b>	5,832,805

#### Station Owner Information

ROI	<b>%</b>	5%
Investment Life	<b>Year</b>	20

#### Capital Costs

Number of Stations	<b>each</b>	3,000
Station Upgrade cost (each)	<b>Dollars</b>	\$600,000
Station Upgrade Expenses (total)	<b>\$</b>	\$1,800,000,000

#### Other Costs

Revenue from Retail Mark-Up	<b>\$/year</b>	\$272,975,294	(assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
Import Fee	<b>\$/GDE</b>	\$0.00	
Annual Import Cost	<b>\$/year</b>	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

### OUTPUTS

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/GDE</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/GDE</b>	<b>\$/GDE</b>
Low LNG Wholesale Cost	\$0.49	\$144,436,657	\$1,164,694,588	\$1,309,131,245	\$0.72	\$0.72
High LNG Wholesale Cost	\$0.71	\$144,436,657	\$1,565,058,353	\$1,709,495,010	\$0.94	\$0.94

(Wholesale costs are based on range of US' annual average spot prices to resellers for 1984 to 2000)

	<b>LNG</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	33,000	112,000	126,000
CA Taxes =	\$0.000	\$0.18	\$0.24
Fed Taxes =	\$0.000	\$0.18	\$0.18
Total Exise Taxes =	\$0.360	\$0.36	\$0.42
Sales Taxes =	0.00%	7.75%	7.75%

cents/gallon			
Annual			
W'sale			
Year	Advanced Diesel	Deflator Index	2002 \$
1984	45.0	67.27	72.7
1985	39.8	69.58	62.1
1986	29.0	71.40	44.1
1987	25.2	73.59	37.2
1988	24.0	76.28	34.2
1989	24.7	79.49	33.8
1990	38.6	82.93	50.6
1991	34.9	86.23	44.0
1992	32.8	88.60	40.2
1993	35.1	90.94	41.9
1994	32.4	93.11	37.8
1995	34.4	95.26	39.2
1996	46.1	97.05	51.6
1997	41.6	98.85	45.7
1998	28.8	100.00	31.3
1999	34.2	101.81	36.5
2000	76.7	103.85	80.2
2001		106.23	
2002		108.64	

Average =	46.07	Cents per gallon
Standard Deviation =	13.79	Cents per gallon
Average Plus Standard Deviation =	\$0.710	Dollars per gallon
Average Minus Standard Deviation =	\$0.490	Dollars per gallon
Mimimum =	\$0.313	(2002\$)
Maximum =	\$0.802	(2002\$)

## **Option 2I**

### **Fischer-Tropsch Diesel**

**(Analysis by Dan Fong)**

#### **Description**

This option considers the adoption of policy (fiscal or regulatory) that would result in greater use of Fischer-Tropsch Diesel (FT Diesel). Such policy could involve a reduction in fuel excise tax for diesel fuel when blended with a percentage of FT Diesel or a diesel fuel specification for cetane number and aromatic content that would encourage the use of FT Diesel over other refinery options.

#### **Background**

FT diesel is made by using a catalyst to convert a feed gas, such as natural gas, into a synthetic diesel fuel. Recent advances in catalyst technology promise competitively priced FT Diesel within the range of possible economic conditions found in the current California diesel fuel market.

FT Diesel can be used directly in some existing stationery engines, and can be made compatible with light and heavy diesel engines for use in vehicles. Preliminary testing in unmodified diesel engines has shown reductions in hydrocarbons (20 percent), carbon monoxide (40 percent), NO<sub>x</sub> (5 percent) and particulate matter (30 percent).

Large quantities of remote natural gas, located too far from urban centers to be piped and used as a local fuel, are very attractive and economic sources of feed gas for producing FT Diesel. Another potentially attractive source of feed gas is gas produced as a byproduct of oil recovery. FT Diesel represents a beneficial supply alternative to conventional diesel fuel, or a blending component to produce greater volumes of low aromatic, lower sulfur diesel.

The nature of the remote location of feed stocks for FT Diesel may be an issue, as they are the same geographical location(s) as imported crude oil. Importing large quantities of FT Diesel may reduce the burden on petroleum diesel supplies, but they may face the same geographic and political issues as crude oil or refined products imported from those regions.

#### **Assumptions and Methodology**

California's diesel fuel, called "CARB diesel" has more restrictive fuel quality specifications than federal diesel, called "EPA diesel." Each gallon of FT Diesel can be blended with 2 gallons of EPA diesel to produce 3 gallons of CARB alternative formulation. The value of FT Diesel as a blending stock can then be 3 times the price differential between CARB diesel and EPA diesel. However, this value should be reduced by an amount, e.g., 1-cent per gallon, to allow a blender/refiner an incentive to implement this blending strategy. For this example, the calculated FT Diesel value would have a range of \$1.19-\$0.87 per gallon (without taxes).

The amount of FT Diesel blended with EPA diesel is estimated from specifications for in-state diesel fuel that have been certified by CARB as alternative formulation diesel. Typical values for the total aromatic content and cetane numbers for FT Diesel and EPA diesel are shown in Table 2I-1. Based upon these specifications and a finished blended diesel with desired aromatic content and cetane number of 20 percent and 55, respectively, the required percentage of FT Diesel that is needed to be blended with EPA diesel is 33.3 percent (FTD33). The desired aromatic and cetane values are within the ranges for alternative diesel formulation specifications certified by CARB.<sup>1</sup>

**Table 2I-1. Diesel Fuel Specifications**

<b>Component</b>	<b>Percentage</b>	<b>Aromatic Content, %</b>	<b>Cetane No.</b>	<b>Wholesale Price/gallon, \$</b>
EPA Diesel	66.7	30	42.5	1.07-0.75
FT Diesel	33.3	0	80	1.21-0.85
Blended Diesel (FTD33)	100	20	55	1.12-.79

The wholesale cost differential between FT Diesel and CARB diesel is about \$.10 per gallon. If CARB diesel is \$0.96/gallon, FT Diesel is then estimated to be \$1.06 per gallon.<sup>2</sup> Since the blending value of FT Diesel brackets this cost, FT Diesel can be an attractive blending component to produce a CARB diesel formulation.

### **Status of Fischer Tropsch Diesel**

Nearly every major oil company has announced plans to produce FT Diesel. Limited imports of FT Diesel over the period from 1993 through 1998 by several refiners were used to blend with heavier, less desirable crude oil to make greater volumes of California's unique low-aromatic CARB diesel fuel.

FT Diesel is being introduced as a blending component for conventional petroleum based diesel fuel. Its use is being driven by a need to produce a diesel fuel with lower aromatic content and higher cetane level. Regulations adopted by the California Air Resources Board (CARB) require that diesel fuel sold in-state be limited to 10 percent by weight total aromatics (CARB diesel) or must meet an alternative formulation that produces equivalent emission benefits. Currently, all diesel fuel produced in California for in-state sale meets optional specifications for total aromatic content and cetane number in lieu of the uniform diesel aromatic content of 10 percent. With a sufficient price differential between CARB diesel and diesel produced for the rest of the U.S. (EPA diesel), FT Diesel can be the most economical option to blend with EPA diesel to produce a CARB alternative formulation diesel.

Today, the major barrier to widespread use of FT Diesel is its cost. At today's diesel prices, FT Diesel costs about 10 cents more per gallon to produce, and retail prices are expected to be 15 to 25 cents per gallon higher than conventional, petroleum-derived diesel. New federal and state fuel specifications will likely increase the cost of conventional diesel, reducing the incremental cost of FT Diesel to 5 to 10 cents per gallon by 2006.

The potential worldwide availability of FT Diesel over time has been projected from industry sources. These values are shown in Table 2I-2. Supply volumes beyond 2020 were extrapolated to 2030.

**Table 2I-2. Worldwide FT Diesel Supply Projections**

Year	Volume	
	Barrels/Day	Gallons/Year, millions
2002	3,500	54
2010	88,000	1,349
2020	180,000	2,759

## Results

**Intermediate Market.** FT Diesel is said to be commercially viable when the price of crude oil exceeds \$20 per barrel. The current price of crude oil is at this level, and expected to average about \$22.50 per barrel during the time period of this analysis. A mature market may be just beginning.

**Mature Market.** Staff examined the cost effectiveness of FT Diesel under a mature market condition, which may very well be just emerging for this fuel. A present value calculation was performed on the incremental cost for owning and operating this fleet over the life of the fleet, 10 years. The results provide an indication of the savings that might accrue to the fleet operator.

This analysis assumes that the incremental retail cost of FT Diesel is 5 to 10 cents higher than EPA diesel. The EPA diesel that would be blended with the FT Diesel is assumed to be 5 cents per gallon lower than the cost of diesel meeting California fuel specifications. A standard deviation in price of \$.17 per gallon was used for high and low retail diesel fuel prices.

No incremental costs are assumed to be required for vehicle acquisition or fuel infrastructure. The key results in this comparison case are projected cost per vehicle per unit reduction in diesel fuel consumption.

FT Diesel would be blended with EPA diesel only when CARB diesel is more expensive. However, the results below include the case when EPA diesel is at a high price and CARB diesel is low, for purposes of consistency with other options. Industry is unlikely to blend FT Diesel into EPA diesel to make CARB diesel in this situation. They would prefer to blend the FT Diesel to make more EPA diesel, so the fourth row on the following table is unlikely.

### 2I-3. Mature Market FT Diesel Fuel

FT Diesel	Conventional Diesel	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consume Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	0	-3,822	-29,511	0	-0.08
Low	Low	0	-179	-1,382	0	0
High	High	0	-3,642	28,125	0	0
High	Low	0	-1	-4	7.88	.08

The mature market scenario compares the long-term cost of deploying FT Diesel as a blending component in diesel fuel to a CARB diesel fuel without FT Diesel. The results show that under a variety of cost conditions for FT Diesel and EPA diesel, the use of FT Diesel to produce a compliant CARB diesel is an economically attractive option, as the “cost” is less than zero (i.e., a savings) for all cases reported.

**Diesel Displacement.** Similar to other options in this group of options, staff assumed that FT diesel could displace 4 percent of the on-road diesel demand in 2010 and ten percent in 2020. Additional reductions in 2030 are expected. These levels of FT diesel would require about 10 percent of the world’s FT diesel supply in 2010 and 15 percent in 2020.

**Table 2I-4. Diesel Displaced by FT Diesel**

	Annual Diesel Reduction		
	2010	2020	2030
Annual Reduction in Diesel Consumption (million gallons)	143	2,759	N/A
Reduction From Base Case Demand (Percent)	4	10	N/A
Percent of global FT Supply (Percent)	10.6	15.1	N/A

### Key Drivers and Uncertainties

The projected demand for FT Diesel depends on the following outcomes and assumptions.

- The worldwide production capacity for FT Diesel must track the supply schedule shown in Table 2I-2. It is reasonable to assume that investment in additional production capacity is likely when crude oil prices are above \$20 per barrel. The pace of investment would be higher at higher oil prices.
- FT Diesel would flow to California if its value were sufficiently attractive for distributors and refiners. This can be assured if the fuel excise tax placed on diesel blended with up to 33.3 percent FT Diesel was reduced by \$.02 to \$.04 per gallon. This should give refiners a sufficient economic advantage to use FT Diesel to produce a diesel fuel meeting California’s alternative diesel formulation requirements.

---

<sup>1</sup> [www.arb.ca.gov](http://www.arb.ca.gov), Certified Alternative Diesel Formulations, February 2002.

<sup>2</sup> The wholesale price of CARB Diesel is derived from the long-term retail price used in the Base Case Demand analysis, \$1.65 per gallon. The retail price results from a (wholesale price + retail margin + federal excise tax + state excise tax) x (state sales tax rate). The wholesale price would include margins for producing and distributing the fuel to consumers, \$.15 per gallon. The federal and state excise taxes for diesel fuel are \$0.243 and \$0.18 per gallon, respectively. A state sales tax rate of 7.75% was employed.

**Option 2I**  
**Fischer-Tropsch Diesel (FT Diesel)**

**Option 2I Fischer-Tropsch Diesel (FTD)**

**INPUTS**

<b>Fleet Information</b>	<b>Units</b>	<b>FTD33*</b>	<b>Units</b>	<b>CARB Diesel</b>
Number of Vehicles	Vehicles	100	Vehicles	100
Annual Mileage	Miles/Vehicle/Year	75,000	Miles/Vehicle/Year	75,000
Fuel Economy	Miles/Gallon	7.0	Miles/Gallon	7.0
Fuel Consumption	Gallons/Year	1,071,429	Gallons/Year	1,071,429
Daily Consumption	Gallons/weekday	3,434	Gallons/weekday	3,434

<b>Fleet Owner Information</b>	<b>Units</b>	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

<b>Vehicle Capital Costs</b>	<b>Units</b>	<b>FTD33*</b>		<b>CARB Diesel</b>	
		<b>High (Near Term)</b>	<b>Low (Long Term)</b>	<b>High</b>	<b>Low</b>
Incremental Vehicle Cost	\$/Vehicle	\$0	\$0	\$0	\$0
Total Incremental Vehicle Cost	\$	\$0	\$0	\$0	\$0
Maintenance Garage Cost	\$	\$0	\$0	\$0	\$0
<b>Fuel Costs</b>	<b>Units</b>	<b>FTD33*</b>		<b>CARB Diesel</b>	
		<b>High Price (High FTD33 + High EPA Diesel)</b>	<b>Low Price (Low FTD33 + Low EPA Diesel)</b>	<b>Baseline + One Standard Deviation</b>	<b>Baseline - One Standard Deviation</b>
Fuel Cost	\$/gal	\$1.82	\$1.46	\$1.82	\$1.48
Annual Fuel Cost	\$/year	\$1,949,946	\$1,567,821	\$1,950,000	\$1,585,714
<b>Government Program Costs</b>		<b>Units</b>			
Start Up Costs	\$	\$0			
Annual Costs	\$/year	\$0			

Blend % 0.333

**OUTPUTS**

	<b>FTD33</b>	<b>CARB Diesel</b>	<b>Incremental Annual Vehicle Capital Cost (FTD33-Diesel)</b>	<b>Incremental Fuel Annual Cost (FTD33-Diesel)</b>	<b>Consumer Cost Net Present Value ("-" Equals Savings)</b>	<b>Change in Excise Taxes ("-" Equals Savings)</b>	<b>Cost To Government</b>	<b>Total \$/Gallon Displaced*</b>	<b>Government Cost \$/Gallon Displaced*</b>	
	<b>Unit</b>		<b>\$</b>	<b>\$/Year</b>	<b>\$</b>	<b>\$</b>	<b>\$</b>	<b>\$/Gallon</b>	<b>\$/Gallon</b>	
Low-High	Low FTD33 #1	High	\$0	-\$382,178.57	-\$2,951,082	\$0	\$0	-\$0.08	\$0.00	L-H
	Low FTD33 #2	High	\$0	-\$139,200.00	-\$1,074,866	\$0	\$0	-\$0.03	\$0.00	not possible
	Mid-Low FTD33 #1	High	\$0	-\$364,339.29	-\$2,813,331	\$0	\$0	-\$0.08	\$0.00	
	Mid-Low FTD33 #2	High	\$0	-\$121,360.71	-\$937,115	\$0	\$0	-\$0.03	\$0.00	not possible
	Mid-High FTD33 #1	High	\$0	-\$260,871.43	-\$2,014,380	\$0	\$0	-\$0.06	\$0.00	not possible
	Mid-High FTD33 #2	High	\$0	-\$17,892.86	-\$138,164	\$0	\$0	\$0.00	\$0.00	
High-High	High FTD33#1	High	\$0	-\$243,032.14	-\$1,876,630	\$0	\$0	-\$0.05	\$0.00	not possible
	High FTD33#2	High	\$0	-\$53.57	-\$414	\$0	\$0	\$0.00	\$0.00	H-H
Low-Low	Low FTD33 #1	Low	\$0	-\$17,892.86	-\$138,164	\$0	\$0	\$0.00	\$0.00	L-L
	Low FTD33 #2	Low	\$0	\$225,085.71	\$1,738,052	\$0	\$1,738,052	\$0.05	\$4.87	not possible
	Mid-Low FTD33 #1	Low	\$0	-\$53.57	-\$414	\$0	\$0	\$0.00	\$0.00	
	Mid-Low FTD33 #2	Low	\$0	\$242,925.00	\$1,875,802	\$0	\$1,875,802	\$0.05	\$5.26	not possible
	Mid-High FTD33 #1	Low	\$0	\$103,414.29	\$798,538	\$0	\$798,538	\$0.02	\$2.24	not possible
	Mid-High FTD33 #2	Low	\$0	\$346,392.86	\$2,674,754	\$0	\$2,674,754	\$0.07	\$7.50	
High-Low	High FTD33#1	Low	\$0	\$121,253.57	\$936,288	\$0	\$936,288	\$0.03	\$2.62	not possible
	High FTD33#2	Low	\$0	\$364,232.14	\$2,812,504	\$0	\$2,812,504	\$0.08	\$7.88	H-L

**Option 21**  
**Fischer-Tropsch Diesel (FT Diesel)**

FTD33	CARB Diesel	Incremental Annual Vehicle Capital Cost (FTD33-Diesel)	Incremental Fuel Annual Cost (FTD33-Diesel)	Consumer Cost Net Present Value ("-" Equals Savings)	Per Vehicle Change in Excise Taxes	Per Vehicle Cost To Government	Net Cost Per Vehicle
<b>Unit</b>		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
Low FTD33 #1	High	\$0	-\$3,822	-\$29,511	\$0	\$0	-\$886
Low FTD33 #1	Low	\$0	-\$179	-\$1,382	\$0	\$0	-\$41
High FTD33#2	Low	\$0	-\$1	-\$4	\$0	\$0	\$0
High FTD33#2	High	\$0	\$3,642	\$28,125	\$0	\$28,125	\$845

("-" represents savings to user; no government cost)

\*The amount of diesel displaced by a gallon of blended FTD33 fuel is 33 percent. The cost per gallon displaced is adjusted for this fraction.

**Option 2I**  
**Fischer-Tropsch Diesel (FT Diesel)**

**STATION COST MODULE Option 2I FT Diesel**

**INPUTS**

Unit	
Fleet Information	
Number of Vehicles	100
Fuel Consumption	Gallons/Year 1,071,429
Daily Consumption	Gallons/weekday

<b>Station Owner Information</b>		
ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

<b>Capital Costs</b>		
Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$0
Station Upgrade Expenses (total)	<b>\$</b>	\$0

<b>Other Costs</b>		
Revenue from Retail Mark-Up	<b>\$/year</b>	\$160,714 (assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
	<b>\$/Gallon</b>	\$0.00
	<b>\$/year</b>	\$0 (assume same CA Import mark-up per million Btu; adjust by Btus)

**OUTPUTS**

	Fuel Cost to Station Owner	Target Return on Capital	Annual Fuel Cost	Target Revenue from Fuel Sales	Target Fuel Price without Taxes	Fuel Price with Taxes
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low FT Diesel Wholesale Cost #1 (Low FT Diesel + Low EPA Diesel)	<b>\$0.79</b>	\$0	\$1,001,840	\$1,001,840	\$0.94	<b>\$1.46</b>
Low FT Diesel Wholesale Cost #2 (Low FT Diesel + High EPA Diesel)	\$1.00	\$0	\$1,227,343	\$1,227,343	\$1.15	\$1.69
Mid-Low FT Diesel Wholesale Cost #1 (Mid-Low FT Diesel + Low EPA Diesel)	<b>\$0.80</b>	\$0	\$1,018,397	\$1,018,397	\$0.95	<b>\$1.48</b>
Mid-Low FT Diesel Wholesale Cost #2 (Mid-Low FT Diesel + High EPA Diesel)	\$1.01	\$0	\$1,243,899	\$1,243,899	\$1.16	\$1.71
Mid-High FT Diesel Wholesale Cost #1 (Mid-High FT Diesel + Low EPA Diesel)	\$0.89	\$0	\$1,114,422	\$1,114,422	\$1.04	\$1.58
Mid-High FT Diesel Wholesale Cost #1 (Mid-High FT Diesel + High EPA Diesel)	<b>\$1.10</b>	\$0	\$1,339,925	\$1,339,925	\$1.25	<b>\$1.80</b>
High FT Diesel Wholesale Cost (High FT Diesel + Low EPA Diesel)	\$0.91	\$0	\$1,130,979	\$1,130,979	\$1.06	\$1.59
High FT Diesel Wholesale Cost (High FT Diesel + High EPA Diesel)	<b>\$1.12</b>	\$0	\$1,356,481	\$1,356,481	\$1.27	<b>\$1.82</b>

	<b>FTD33</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	126,000	112,000	126,000
CA Taxes =	\$0.243	\$0.18	\$0.24
Fed Taxes =	\$0.180	\$0.18	\$0.18
Total Exise Taxes =	\$0.423	\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

## Option 21 FT Diesel

	A	B	C	D	E	F	G	H	I	J	K	L	
1	FT Diesel and EPA/CARB Diesel Cost												
2	Mature FT Diesel (FTD100) Incremental Cost vs. CARB Diesel							\$0.05	\$0.10				
3													
4	Low FT Diesel (FTD100) Retail Cost				\$/gallon	\$1.53	\$0.05 diff. between FT and CARB						
5	Low FT Diesel (FTD100) Wholesale Cost				\$/gallon	\$0.85							
6													
7	Mid-Low FT Diesel (FTD100) Retail Cost				\$/gallon	\$1.58	\$0.10 diff. between FT and CARB						
8	Mid-Low FT Diesel (FTD100) Wholesale Cost				\$/gallon	\$0.89							
9													
10	Mid-High FT Diesel (FTD100) Retail Cost				\$/gallon	\$1.87	\$0.05						
11	Mid-High FT Diesel (FTD100) Wholesale Cost				\$/gallon	\$1.16							
12													
13	High FT Diesel (FTD100) Retail Cost				\$/gallon	\$1.92							\$0.10
14	High FT Diesel (FTD100) Wholesale Cost				\$/gallon	\$1.21							
15													
16	Low CARB Diesel Retail Cost				\$/gallon	\$1.48							
17	Low CARB Diesel Retail Cost w/o Sales Tax				\$/gallon	\$1.37	Fed Tax		State Tax				
18	Low CARB Diesel Retail Cost w/o Sales Tax and Excise Taxes				\$/gallon	\$0.95	\$0.24		\$0.18				
19	w/o average retail margin (O&M&profit)				\$/gallon	\$0.80							
20	Low CARB Diesel Wholesale Cost				\$/gallon	\$0.80							
21													
22													
23	High CARB Diesel Retail Cost				\$/gallon	\$1.82							
24	High CARB Diesel Retail Cost w/o Sales Tax				\$/gallon	\$1.69							
25	Low CARB Diesel Retail Cost w/o Sales Tax and Excise Taxes				\$/gallon	\$1.27							
26	w/o average retail margin (O&M&profit)				\$/gallon	\$1.12	Price differential between CARB Diesel and EPA Diesel varies. Data reviewed by J.Page (2/6/02) indicates the average may be \$.03 to \$.05 per gallon. This analysis assumes the retail CARB diesel price is \$.05 per gallon higher.						
27	High CARB Diesel Wholesale Cost				\$/gallon	\$1.12							
28													
29	Low EPA Diesel Retail Cost				\$/gallon	\$1.43							
30	Low EPA Diesel Retail Cost w/o Sales Tax				\$/gallon	\$1.33							
31	Low EPA Diesel Retail Cost w/o Sales Tax and Excise Taxes				\$/gallon	\$0.90							
32	w/o average retail margin (O&M&profit)				\$/gallon	\$0.75							
33	Low EPA Diesel Wholesale Cost				\$/gallon	\$0.75							
34													
35	High EPA Diesel Retail Cost				\$/gallon	\$1.77							
36	High EPA Diesel Retail Cost w/o Sales Tax				\$/gallon	\$1.64							
37	High EPA Diesel Retail Cost w/o				\$/gallon	\$1.22							
38	w/o average retail margin (O&M&profit)				\$/gallon	\$1.07							
39	High EPA Diesel Wholesale Cost				\$/gallon	\$1.07							
40													
41	In lieu of a diesel fuel with a total aromatic content that does not exceed 10 percent,												
42	a process exists for the Air Resources Board to certify that an alternative formulation												
43	results in equivalent emissions benefits. From published specifications of certified alternative												
44	formulations, one can estimate the proportions of FTD and EPA diesel that might be blended												
45	to produce equivalent emission results.												
46													
47	Aromatic		Cetane										
48	EPA diesel	30	42.5										
49													

Fed Tax	State Tax
\$0.24	\$0.18

Price differential between CARB Diesel and EPA Diesel varies. Data reviewed by J.Page (2/6/02) indicates the average may be \$.03 to \$.05 per gallon. This analysis assumes the retail CARB diesel price is \$.05 per gallon higher.

**Option 21**  
**FT Diesel**

	A	B	C	D	E	F	G	H	I	J	K	L
50	FTD	0	80									
51												
52	FTD Blend											
53	0.25	22.5	51.875									
54	0.3	21	53.75									
55	0.333	20.01	54.9875									
56	0.35	19.5	55.625									
57	0.4	18	57.5									
58	0.45	16.5	59.375									
59	0.5	15	61.25									
60												
61				FTD Blend%		0.333						
62						FTD33		CARB Diesel	FTD33-CARB Diesel			
63	Low FTD + Low EPA Diesel				\$/gallon	\$0.79		\$0.80	-\$0.02	possible		
64								\$1.12	-\$0.33			
65	Low FTD + High EPA Diesel				\$/gallon	\$1.00		\$0.80	\$0.19	not possible; FTD33 linked to CARB		
66								\$1.12	-\$0.12			
67	Mid-Low FTD + Low EPA Diesel				\$/gallon	\$0.80		\$0.80	\$0.00	possible		
68								\$1.12	-\$0.32			
69	Mid-Low FTD + High EPA Diesel				\$/gallon	\$1.01		\$0.80	\$0.21	not possible; FTD33 linked to CARB		
70								\$1.12	-\$0.11			
71	Mid-High FTD + Low EPA Diesel				\$/gallon	\$0.89		\$0.80	\$0.09	not possible; FTD33 linked to CARB		
72								\$1.12	-\$0.23			
73	Mid-High FTD + High EPA Diesel				\$/gallon	\$1.10		\$0.80	\$0.30	possible		
74								\$1.12	-\$0.02			
75	High FTD + Low EPA Diesel				\$/gallon	\$0.91		\$0.80	\$0.11	not possible; FTD33 linked to CARB		
76								\$1.12	-\$0.21			
77	High FTD + High EPA Diesel				\$/gallon	\$1.12		\$0.80	\$0.32	possible		
78								\$1.12	\$0.00			

## **Option 2J Biodiesel (Analysis by Dan Fong)**

### **Description**

This option is the adoption of incentives to reduce the consumer cost of biodiesel fuel for use as a lubricity agent and 20 percent blending component in diesel fuel for heavy-duty vehicles.

### **Background**

Biodiesel is made by reacting any natural oils or fats with alcohol (usually methanol). It can be used in neat form (B100) or as a blendstock to extend the supply of conventional, petroleum-derived diesel (used at a 20 percent biodiesel to 80 percent conventional diesel, it is called B20).

Biodiesel fuels are typically made from soybean oils, rapeseed oil, animal fats or recycled cooking greases. Using 2 percent by volume biodiesel (called B2) blended into conventional, petroleum-derived diesel can provide an alternative fuel lubricity option.<sup>1</sup> When blended at 20 percent with conventional diesel fuel, the resultant mixture has demonstrated generally lower emissions compared to diesel (11 percent lower hydrocarbons, 12 percent lower carbon monoxide emissions, and 19 percent lower particulate matter; NO<sub>x</sub> emissions are not improved).

Biodiesel has low sulfur levels, and can be used as a blend stock to reduce the overall sulfur content of some diesels. Biodiesel sulfur levels are typically lower than 2006 federal sulfur requirements. Biodiesel has a higher flash point than petroleum diesel, and can be used in most applications in the same manner as conventional petroleum diesel. One notable exception is that special handling and heaters may be required in cold weather applications. Also, there may be some materials compatibility issues with seals and gaskets in engines manufactured before 1994. At the present time, the practice is to limit the percentage of biodiesel to no more than 20 percent (B20) to avoid these problems.

Neat biodiesel (B100) has a lower energy content than conventional diesel. The energy content of biodiesel is about 121,000 Btu per gallon while conventional diesel is about 135,000 btu per gallon. The U.S. Department of Energy's Office of Transportation Technologies has estimated the net energy balance for biodiesel. For every gallon of petroleum fuel used to produce it, 3.37 gallons of biodiesel are produced.<sup>2</sup>

### **Assumptions and Methodology**

Since biodiesel can be used in existing diesel engines without modification at levels of B20 and below, there is no incremental cost related to vehicle purchase. The existing diesel fuel infrastructure can also store and dispense biodiesel without modification.

In this analysis, staff used literature estimates of the cost of biodiesel, and determine the cost of B2 and B20 by ratio, adding \$.01 per gallon as an adequate blending incentive to refiners. Staff

made estimates of the future retail B20 costs based upon expected future wholesale costs and ordinary mark up. Results range from \$.04 to \$.25 per gallon less than diesel.

### Status of Biodiesel

The supply of biodiesel is limited today by its significantly higher production cost. Presently, B20 costs 13 to 22 cents per gallon more than petroleum diesel.<sup>3</sup> When used in its pure form (B100), biodiesel costs between \$1.25 and \$2.25 per gallon depending on purchase volume and delivery costs.<sup>4</sup>

The U.S. DOE is conducting research to reduce the cost of producing biodiesel and to expand supplies using novel feed stocks and new production technologies. A portion of the work is directed at reducing NO<sub>x</sub> emissions.

The projected national supply of biodiesel is shown in Table 2J-1.

**Table 2J-1. Projected Biodiesel Supply<sup>5</sup>**

Year	Volume, millions of gallons
2002	4
2010	1,000
2020	6,000

### Results

**Intermediate Market.** Currently, the cost of B2 is \$0.013 to \$0.022 per gallon above conventional diesel. Considerable research and development efforts are needed to reduce the price to a point where it could become competitive with petroleum-based diesel. If an intermediate market for biodiesel develops, staff expects it will be as an alternative fuel lubricity option in the form of B2. Staff expects the price of B2 to be closely tied to the price of conventional diesel, so only report results when both fuel prices are “low” or “high.”

**Table 2J-1. Intermediate Market Biodiesel (B2)**

FCV	Gasoline ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consume Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	N/A	N/A	N/A	N/A	N/A
Low	Low	0	92	712	0.33	0.33
High	High	0	19	150	0.07	0.07
High	Low	N/A	N/A	N/A	N/A	N/A

Staff assumed that government covers any increased cost to the consumer. Hence, the reporting of life cycle government costs equaling overall costs.

**Mature Market.** A mature market scenario is used to estimate the potential incremental cost to operate a typical fleet of vehicles using B20. This scenario calculates the incremental cost of B20 based upon a B100 wholesale cost of \$1.20 per gallon. It would then be blended with a CARB diesel fuel. A standard deviation in price of \$.17 per gallon was used for high and low retail diesel fuel prices.

No incremental costs are assumed to be required for vehicle acquisition or fuel infrastructure. The key results in this comparison case are projected cost per vehicle per unit reduction in petroleum fuel consumption and related net present values of needed government investments. The results provide an indication of the amount of investment needed to neutralize the higher cost of the displacement option compared to the conventional fuel option. Staff expects the price of B2 to be closely tied to the price of conventional diesel, so only report results when both fuel prices are “low” or “high.”

**Table 2J-2. Mature Market Biodiesel (B20)**

FCV	Gasoline ICE	Incremental Vehicle Capital Cost	Incremental Annual Fuel Cost	Life Cycle Consume Cost	Life Cycle Government Cost	Life Cycle Overall Cost
Combined Capital & Fuel Costs, \$		\$/Vehicle	\$/Vehicle-Year	\$/Vehicle	\$/Gallon	\$/Gallon
Low	High	N/A	N/A	N/A	N/A	N/A
Low	Low	0	1,288	9,948	0.46	0.46
High	High	0	2,975	22,974	1.07	1.07
High	Low	N/A	N/A	N/A	N/A	N/A

Staff assumed that government covers any increased cost to the consumer. Hence, the reporting of life cycle government costs equaling overall costs. In this option, in a mature market the government loses excise taxes of \$92 per vehicle per year.

**Diesel Displacement.** Similar to other options in this group of options, staff assumed that both B2 and B20 biodiesel blends are used in 4 percent of the diesel fuel supply in 2010 and ten percent in 2020. Additional reductions in 2030 are expected.

<b>B2 Biodiesel</b>	<b>Annual Diesel Reduction</b>		
	<b>2010</b>	<b>2020</b>	<b>2030</b>
Annual Reduction in Diesel Consumption (million gallons)	2.9	8.3	N/A
Reduction From Base Case Demand (Percent)	4	10	N/A

<b>B20 Biodiesel</b>	<b>Annual Diesel Reduction</b>		
	<b>2010</b>	<b>2020</b>	<b>2030</b>
Annual Reduction in Diesel Consumption (million gallons)	28.6	83.5	N/A
Reduction From Base Case Demand (Percent)	4	10	N/A

These levels of biodiesel would require only about 3.1 percent of the world’s biodiesel supply in 2010 and 1.5 percent in 2020.

## **Key Drivers and Uncertainties**

1. Although the projected supply of biodiesel appears sufficient, demand in other regions of the country would have to increase to support the required investment in production capacity.
2. It is likely that any reduction in fuel excise tax used to support the higher cost of biodiesel would have to be offset by higher revenues from another source.
3. The production cost of biodiesel is expected to decrease as technology improves and production scale-up reduces unit costs.

---

<sup>1</sup> U. S. DOE, Office of Transportation Technologies, [http://www.ott.doe.gov/biofuels/renewable\\_diesel.html](http://www.ott.doe.gov/biofuels/renewable_diesel.html)

<sup>2</sup> U.S. DOE, Office of Transportation Technologies web site, "Biodiesel Benefits."

<sup>3</sup> U.S. Department of Energy, Clean Cities Alternative Fuel Information Series, Fact Sheet, May 2001

<sup>4</sup> Ibid.

<sup>5</sup> Supply projections based upon staff communication between Gary Yowell and Dr. K. Shaine Tyson, National Renewable Energy Laboratory, August 2001.

**Option 2J  
Biodiesel (B2)**

**Option 2J Biodiesel (B2)--Intermediate Market**

**INPUTS**

Fleet Information	Units	Biodiesel (B2)*	Units	Diesel
Number of Vehicles	Vehicles	100	Vehicles	100
Annual Mileage	Miles/Vehicle/Year	75,000	Miles/Vehicle/Year	75,000
Fuel Economy	Miles/Gallon	7.0	Miles/Gallon	7.0
Fuel Consumption	Gallons/Year	1,071,429	Gallons/Year	1,071,429
Daily Consumption	Gallons/weekday	3,434	Gallons/weekday	3,434

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Biodiesel (B2)		CARB Diesel	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$0	\$0	\$0	\$0
Total Incremental Vehicle Cost	\$	\$0	\$0	\$0	\$0
Maintenance Garage Cost	\$	\$0	\$0	\$0	\$0
Fuel Costs	Units	Biodiesel (B2)		CARB Diesel	
		High Price (B100 + High Diesel)	Low Price (B100 + Low Diesel)	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$1.842	\$1.493	\$1.82	\$1.48
Annual Fuel Cost	\$/year	\$1,951,937	\$1,594,937	\$1,950,000	\$1,585,714
Government Program Costs		Units			
Start Up Costs	\$	\$0			
Annual Costs	\$/year	\$0			
Years of Annual Government Costs	Years	5			

**OUTPUTS**

	B2	CARB Diesel	Incremental Annual Vehicle Capital Cost (B2-Diesel)	Incremental Fuel Annual Cost (B2-Diesel)	Consumer Cost Net Present Value ("-" Equals Savings)	Change in Excise Taxes ("-" Equals Savings)	Cost To Government	Total \$/Gallon Displaced*	Government Cost \$/Gallon Displaced*
	Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
(exclude)	Low	High	\$0	-\$355,062.70	-\$2,741,700	\$0	\$0	-\$12.795	\$0.000
	Low	Low	\$0	\$9,223.02	\$71,218	\$0	\$71,218	\$0.332	\$0.332
	High	High	\$0	\$1,937.30	\$14,959	\$0	\$14,959	\$0.070	\$0.070
(exclude)	High	Low	\$0	\$366,223.02	\$2,827,877	\$0	\$2,827,877	\$13.197	\$13.197

	B2	CARB Diesel	Incremental Annual Vehicle Capital Cost (B2-Diesel)	Incremental Fuel Annual Cost (B2-Diesel)	Consumer Cost Net Present Value ("-" Equals Savings)	Per Vehicle Change in Excise Taxes	Per Vehicle Cost To Government	Net Cost Per Vehicle	
	Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle	
(exclude)	Low	High	\$0	-\$3,551	-\$27,417	\$0	\$0	-\$27,417	(Exclude)
	Low	Low	\$0	\$92	\$712	\$0	\$712	\$712	
	High	High	\$0	\$19	\$150	\$0	\$150	\$150	
(exclude)	High	Low	\$0	\$3,662	\$28,279	\$0	\$28,279	\$28,279	(Exclude)

("-" represents savings to user; no government cost)

\*The amount of diesel displaced by a gallon of B2 fuel is 2 percent. The cost per gallon displaced is adjusted for this fraction.

**Option 2J  
Biodiesel (B2)**

**STATION COST MODULE Option 2J Biodiesel--Intermediate Market**

**INPUTS**

Unit

**Fleet Information**

Number of Vehicles		100
Fuel Consumption	<b>Gallons/Year</b>	1,071,429
Daily Consumption	<b>Gallons/weekday</b>	

**Station Owner Information**

ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

**Capital Costs**

Number of Stations	<b>each</b>	1
Station Upgrade cost (each)	<b>Dollars</b>	\$0
Station Upgrade Expenses (total)	<b>\$</b>	\$0

**Other Costs**

Revenue From Retail Mark-Up	<b>\$/year</b>	\$160,714	(assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
	<b>\$/Gallon</b>	\$0.00	
	<b>\$/year</b>	\$0	(assume same CA Import mark-up per million Btu; adjust by Btus)

**OUTPUTS**

	<b>Fuel Cost to Station Owner</b>	<b>Target Return on Capital</b>	<b>Annual Fuel Cost</b>	<b>Target Revenue from Fuel Sales</b>	<b>Target Fuel Price without Taxes</b>	<b>Fuel Price with Taxes</b>
	<b>\$/gallon</b>	<b>\$/year</b>	<b>\$/year</b>	<b>\$</b>	<b>\$/gal</b>	<b>\$/gal</b>
Low B2 Wholesale Cost (Low B100 + Low Diesel)	\$0.81	\$0	\$1,027,006	\$1,027,006	\$0.96	\$1.49
Mid-Hi B2 Wholesale Cost (Low B100 + High Diesel)	\$1.12	\$0	\$1,358,328	\$1,358,328	\$1.27	\$1.82
Mid-Low B2 Wholesale Cost (High B100 + Low Diesel)	\$0.00	\$0	\$160,714	\$160,714	\$0.15	\$0.62
High B2 Wholesale Cost (High B100 + High Diesel)	\$0.00	\$0	\$160,714	\$160,714	\$0.15	\$0.62

	<b>Alt Fuel</b>	<b>Gasoline</b>	<b>Diesel</b>
LHV Energy Content =	126,000	112,000	126,000
CA Taxes =	\$0.243	\$0.18	\$0.24
Fed Taxes =	\$0.180	\$0.18	\$0.18
Total Exise Taxes =	\$0.423	\$0.36	\$0.42
Sales Taxes =	7.75%	7.75%	7.75%

**Option 2J  
Biodiesel (B2)**

	A	B	C	D	E	F	G	H	I
1	<b>B2 and Diesel Cost</b>								
2									
3	Low B100 Wholesale Cost w/o delivery cost (\$.04/gallon)				\$/gallon	\$1.20			
4	High B100 Wholesale Cost w/o delivery cost (\$.04/gallon)				\$/gallon	\$2.20			
5									
6	Low Diesel Retail Cost				\$/gallon	\$1.48			
7	Low Diesel Retail Cost w/o Sales Tax				\$/gallon	\$1.37			
8	Low Diesel Retail Cost w/o Sales Tax and Excise Taxes				\$/gallon	1.0			
9	w/o average retail margin (O&M&profit)				\$/gallon	\$0.80			
10	Low Diesel Wholesale Cost				\$/gallon	\$0.80			
11									
12									
13	High Diesel Retail Cost				\$/gallon	\$1.82			
14	High Diesel Retail Cost w/o Sales Tax				\$/gallon	\$1.69			
15	Low Diesel Retail Cost w/o Sales Tax and Excise Taxes				\$/gallon	\$1.27			
16	w/o average retail margin (O&M&profit)				\$/gallon	\$1.12			
17	High Diesel Wholesale Cost				\$/gallon	\$1.12			
18									
19							B2	Diesel	B2-Diesel
20	Low B100 + Low Diesel		L/L B20	\$/gallon	\$0.81		\$0.80	\$0.01	
21	Low B100 + High Diesel		L/H B20	\$/gallon	\$1.12		\$1.12	\$0.00	

Fed Tax	State Tax
\$0.24	\$0.18

**Option 2J  
Biodiesel (B20)**

**Option 2J Biodiesel (B20)--Mature Market**

**INPUTS**

Fleet Information	Units	Biodiesel (B20)*	Units	Diesel
Number of Vehicles	Vehicles	100	Vehicles	100
Annual Mileage	Miles/Vehicle/Year	75,000	Miles/Vehicle/Year	75,000
Fuel Economy	Miles/Gallon	6.9	Miles/Gallon	7.0
Fuel Consumption	Gallons/Year	1,093,294	Gallons/Year	1,071,429
Daily Consumption	Gallons/weekday	3,504	Gallons/weekday	3,434

Fleet Owner Information	Units	
Capital Amortization Rate	%	5%
Vehicle Life	Year	10

Vehicle Capital Costs	Units	Biodiesel (B20)		CARB Diesel	
		High	Low	High	Low
Incremental Vehicle Cost	\$/Vehicle	\$0	\$0	\$0	\$0
Total Incremental Vehicle Cost	\$	\$0	\$0	\$0	\$0
Maintenance Garage Cost	\$	\$0	\$0	\$0	\$0
Fuel Costs	Units	Biodiesel (B20)		CARB Diesel	
		High Price (High B100 + High Diesel)	Low Price (Low B100 + Low Diesel)	Baseline + One Standard Deviation	Baseline - One Standard Deviation
Fuel Cost	\$/gal	\$2.056	\$1.568	\$1.820	\$1.480
Annual Fuel Cost	\$/year	\$2,247,525	\$1,714,544	\$1,950,000	\$1,585,714

**OUTPUTS**

	B20	Diesel	Incremental Annual Vehicle Capital Cost (B20-Diesel)	Incremental Fuel Annual Cost (B20-Diesel)	Consumer Cost Net Present Value ("-" Equals Savings)	Change in Excise Taxes ("-" Equals Savings)	Cost To Government	Total \$/Gallon Displaced*	Government Cost \$/Gallon Displaced*
	Unit		\$	\$/Year	\$	\$	\$	\$/Gallon	\$/Gallon
(exclude)	Mid-High	High	\$0	\$61,920	\$478,133	-\$9,249	\$468,883	\$0.219	\$0.219
(exclude)	Mid-Low	Low	\$0	\$364,435	\$2,814,070	-\$9,249	\$2,804,821	\$1.309	\$1.309
	Low	Low	\$0	\$128,830	\$994,791	-\$9,249	\$985,542	\$0.460	\$0.460
	High	High	\$0	\$297,525	\$2,297,412	-\$9,249	\$2,288,162	\$1.068	\$1.068

	B20	Diesel	Incremental Annual Vehicle Capital Cost (B20-Diesel)	Incremental Fuel Annual Cost (B20-Diesel)	Consumer Cost Net Present Value ("-" Equals Savings)	Per Vehicle Change in Excise Taxes	Per Vehicle Cost To Government	Net Cost Per Vehicle
	Unit		\$/vehicle	\$/vehicle/year	\$/vehicle	\$/vehicle	\$/vehicle	\$/vehicle
	Mid-High	High	\$0	\$619	\$4,781	-\$92	\$4,689	\$4,689
	Mid-Low	Low	\$0	\$3,644	\$28,141	-\$92	\$28,048	\$28,048
	Low	Low	\$0	\$1,288	\$9,948	-\$92	\$9,855	\$9,855
	High	High	\$0	\$2,975	\$22,974	-\$92	\$22,882	\$22,882

("-" represents savings to user; no government cost)

\* The amount of diesel displaced by a gallon of B20 fuel is 20 percent. The cost per gallon displaced is adjusted for this fraction.

**Option 2J  
Biodiesel (B20)**

**STATION COST MODULE Option 2J Biodiesel**

**INPUTS**

Unit	
Fleet Information	
Number of Vehicles	100
Fuel Consumption	Gallons/Year 1,093,294
Daily Consumption	Gallons/weekday

<b>Station Owner Information</b>		
ROI	<b>%</b>	12%
Investment Life	<b>Year</b>	20

<b>Capital Costs</b>		
Number of Stations	<b>each</b>	0
Station Upgrade cost (each)	<b>Dollars</b>	
Station Upgrade Expenses (total)	<b>\$</b>	\$0

<b>Other Costs</b>		
Revenue From Retail Mark-Up	<b>\$/year</b>	\$163,994 (assume same retail mark-up <u>per gallon</u> as gasoline, \$0.15/gallon)
CA Import Margin	<b>\$/Gallon</b>	\$0.00
CA Import Cost	<b>\$/year</b>	\$0 (assume same CA Import mark-up per million Btu; adjust by Btus)

**OUTPUTS**

	Fuel Cost to Station Owner	Target Return on Capital	Annual Fuel Cost	Target Revenue from Fuel Sales	Target Fuel Price without Taxes	Fuel Price with Taxes	
	\$/gallon	\$/year	\$/year	\$	\$/gal	\$/gal	
Low B20 Wholesale Cost (Low B100 + Low Diesel)	\$0.88	\$0	\$1,128,761	\$1,128,761	\$1.03	\$1.57	\$0.25
Mid-Hi B20 Wholesale Cost (Low B100 + High Diesel)	\$1.13	\$0	\$1,404,748	\$1,404,748	\$1.28	\$1.84	-\$0.02
Mid-Low B20 Wholesale Cost (High B100 + Low Diesel)	\$1.08	\$0	\$1,347,420	\$1,347,420	\$1.23	\$1.78	\$0.04
High B20 Wholesale Cost (High B100 + High Diesel)	\$1.33	\$0	\$1,623,407	\$1,623,407	\$1.48	\$2.06	-\$0.24

	B20	Gasoline	Diesel
LHV Energy Content =	132,200	112,000	135,000
CA Taxes =	\$0.243	\$0.18	\$0.243
Fed Taxes =	\$0.180	\$0.18	\$0.180
Total Exise Taxes =	\$0.423	\$0.36	\$0.423
Sales Taxes =	7.75%	7.75%	7.75%

	A	B	C	D	E	F	G	H	I
1	B20 and Diesel Cost								
2									
3	Low B100 Wholesale Cost w/o delivery cost (\$.04/gallon)				\$/gallon	\$1.21			
4	High B100 Wholesale Cost w/o delivery cost (\$.04/gallon)				\$/gallon	\$2.21			
5									
6	Low Diesel Retail Cost				\$/gallon	\$1.48			
7	Low Diesel Retail Cost w/o Sales Tax				\$/gallon	\$1.37			
8	Low Diesel Retail Cost w/o Sales Tax and Excise Taxes				\$/gallon	1.0			
9	w/o average retail margin (O&M&profit)				\$/gallon	\$0.80			
10	Low Diesel Wholesale Cost				\$/gallon	\$0.80			
11									
12									
13	High Diesel Retail Cost				\$/gallon	\$1.82			
14	High Diesel Retail Cost w/o Sales Tax				\$/gallon	\$1.69			
15	Low Diesel Retail Cost w/o Sales Tax and Excise Taxes				\$/gallon	\$1.27			
16	w/o average retail margin (O&M&profit)				\$/gallon	\$1.12			
17	High Diesel Wholesale Cost				\$/gallon	\$1.12			
18									
19							B20	Diesel	B20-Diesel
20	Low B100 + Low Diesel			L/L B20	\$/gallon	\$0.88		\$0.80	\$0.08
21	Low B100 + High Diesel			L/H B20	\$/gallon	\$1.13		\$1.12	\$0.02
22	High B100 + Low Diesel			H/L B20	\$/gallon	\$1.08		\$0.80	\$0.28
23	High B100 + High Diesel			H/H B20	\$/gallon	\$1.33		\$1.12	\$0.22

## **GROUP 3 PRICING OPTIONS**

## **Option 3A Gasoline Tax (Analysis by Chris Kavalec)**

### **Description**

This option examines the effect of increasing the tax on gasoline in California by 50 cents per gallon for the period 2003-2020.

### **Background**

A higher gasoline tax would reduce the consumption of gasoline through two mechanisms. First, the additional tax would increase the per-mile cost of driving, reducing vehicle miles traveled. Second, the tax would provide an incentive for vehicle owners to purchase a more fuel efficient vehicle, as this would reduce exposure to the tax. This second mechanism, which would take place over time, would lead to greater reductions in gasoline demand in the medium and long term relative to the short term (as shown in Table 3A-1).

### **Assumptions and Methodology**

The Commission's CALCARS model was used to simulate this option. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

The price of gasoline was increased by 50 cents, and this increase affected miles driven, vehicle choice, and vehicle demand. The higher gasoline tax was assumed to affect personal vehicles only, as the models used by the Commission for commercial fleet and freight energy demand are currently not behaviorally based.

Revenues from the tax would presumably provide a benefit to California in some form (perhaps through a rebate or a reduction in another type of state tax) and are therefore shown as a benefit in Table 3A-2.

### **Results**

Table 3A-1 shows the projected reductions in gasoline demand for the years 2010, 2020, and 2030 in California, in both absolute and percentage terms. These reductions correspond to price elasticities of demand for gasoline (that is, the percentage change in gasoline demand divided by the percentage change in fuel price) of  $-0.14$ ,  $-0.145$ , and  $-0.15$  in 2010, 2020, and 2030, respectively. The elasticities increase in absolute terms as households react to the increase in gasoline price by changing the fleet mix over time.

**Table 3A-1. Gasoline Demand Reductions from 50 Cent Higher Fuel Tax**

	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	745	891	1,051
Reduction From Base Case Demand (percent)	4.35	4.56	4.69

\*Gasoline displacement.

Table 3A-2 shows the net benefit results for consumers and the impact on government revenues (in this case a positive net benefit), in present value terms, for 2010, 2020, and 2030, for a 5 percent discount rates. These calculations are net amounts relative to the base case forecast. The negative consumer benefits (also known as the change in consumer surplus) are equal to the higher cost per mile times the new (lower) level of VMT, plus the lost benefits to motorists due to reduced driving (known as the “deadweight” loss to society). The state government sees a large increase in revenues, which is counted as a positive net benefit. The sum of these two impacts is shown as “Non-Environmental Direct Benefits,” and represents direct benefits excluding the “external” beneficial effects of reduced driving and gasoline demand (e.g., less congestion, less gasoline-related pollution). These entries are negative, reflecting this deadweight loss.<sup>1</sup> However, once environmental effects are considered, total direct benefits may be positive.

Although gasoline demand is reduced, the reduction in gasoline excise tax revenues is not included as part of the impact on government revenues in this case. It is assumed that required highway expenditures (funded in part by gasoline taxes) are roughly proportional to vehicle miles traveled, so that the reduction in driving brought about by the higher gasoline tax decreases the costs of highway service and maintenance.<sup>2</sup> Thus less revenue is required for these purposes, and the reduction in required revenue is assumed to be approximately the same as the loss in excise taxes.

**Table 3A-2. Present Value (2002 Benchmark, 5% Discount Rate) of Direct Net Benefits of 50 Cent Gasoline Tax Relative to Base Forecast (million 2001\$)**

Time Period	Net Consumer Benefits (A)	Government Revenues (B)	Non-Environmental Net Direct Benefits (A+B)
2002-2010	-38,156	37,278	-878
2002-2020	-73,599	71,922	-1,677
2002-2030	-98,478	96,241	-2,237

### Key Drivers and Uncertainties

The future price of gasoline would play a key role in the impact of a higher gasoline tax. If gasoline prices are significantly higher than what is projected in the Base Case forecast, the impact of a higher tax on gasoline demand would be reduced, since discretionary driving (the first type of driving to be affected by higher gasoline prices) would already be at a lower level. Aside from gasoline price, the key driver for the results described above is the response by households to higher gasoline prices predicted by the CALCARS model. It should be noted that price elasticities of gasoline demand endogenous to the model are consistent with most other empirical work.

---

<sup>1</sup> The higher cost of driving per mile times the new VMT is equal to the increase in government revenue. The net loss to consumers therefore exceeds the gain in revenue by the amount of the deadweight loss.

<sup>2</sup> Staff used a study by the California Department of Transportation called the *Highway Cost Allocation Study* (California Department of Transportation, 1987) to estimate the relative cost attributable to highway expenditures by vehicle type. It was estimated that around 73 percent of total maintenance costs can be attributed to car and light truck vehicle miles traveled.

## **Option 3B**

### **Pay-at-the-Pump Auto Insurance**

**(Analysis by Chris Kavalec)**

#### **Description**

This option examines the effect of implementing a pay-at-the-pump auto insurance system in California for 2003-2030 for light-duty vehicles.

#### **Background**

In recent years, pay-at-the-pump (PATP) insurance has attracted a great deal of attention as an alternative to the current insurance market. PATP insurance proposals have historically been proposed so that at least some portion of auto insurance is covered through a higher fuel tax, with the rest paid either as an increment to registration fees or directly to an insurance company. The best-known proposals have also included a no-fault provision, so that drivers in an accident would be paid damages by their own insurance company, regardless of who was at fault.<sup>1</sup> This analysis considers only the PATP aspect.

PATP proposals have been touted as money-savers for currently insured motorists through two mechanisms. First, the fuel surcharge means that uninsured motorists would have to pay at least some insurance, so that uninsured motorist coverage now paid by insured drivers would be reduced or eliminated. Second, proponents of no-fault argue that resulting reductions in legal costs would lead to a further decrease in insurance premiums.

Another appealing aspect of PATP is that it would more closely link the cost of insurance to vehicle miles traveled (VMT). The more miles driven, all else equal, the greater the exposure to accidents. The current system of pricing is inefficient since insurance is perceived by motorists as a fixed cost, whereas it is quite likely that at least a portion of accident risk is a variable component related to VMT.<sup>2</sup> Therefore, through more efficient pricing of insurance, PATP has potential welfare benefits.

Because PATP insurance would increase the marginal cost of driving through a higher fuel tax, VMT and gasoline use should decrease. This would occur because many motorists would likely drive less or switch to a more efficient vehicle to reduce exposure to the higher tax (either within the household's current fleet or through replacement of a currently held vehicle), and average vehicle fuel economy should increase. Therefore, PATP acts as a travel demand measure, and external costs related to both driving (e.g., congestion) and gasoline use (e.g., global warming) would be expected to fall. Furthermore, these benefits may not require an increase in private costs for the average motorist.

#### **Assumptions and Methodology**

The Commission's CALCARS model was used to simulate this option. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for

California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

In this analysis, the minimum amount of liability insurance required by California law is paid through a fuel surcharge, beginning in 2003. Vehicle fixed costs are therefore reduced while marginal costs increase. In previous work, the cost for this minimum amount of insurance was estimated to be between \$150 and \$400, depending on the insurance company and the geographic area. In this simulation, the cost was assumed to be \$250. This translated to roughly 2.1 cents per vehicle mile traveled by personal vehicles, collected through a gasoline surcharge of around 43 cents (slightly more in some years and less in others), added to the price of gasoline. At the same time, fixed costs per vehicle were reduced by \$250. Note that the critical assumption that must be made is that the portion of accident risk transferred to a marginal cost is proportional to VMT.

Since it is required by law, it was assumed that all drivers in California would carry minimum insurance without PATP. However, the impacts of relaxing this assumption are discussed below.

PATP was assumed to affect personal vehicles only, as the models used by the Commission for commercial fleet and freight energy demand are currently not behaviorally based.

All other assumptions are identical to those made in the base case forecast.

## Results

Table 3B-1 shows the projected reductions in gasoline demand for the years 2010, 2020, and 2030 in California, in both absolute and percentage terms. Similar to the gasoline tax analysis, annual reductions in gasoline demand relative to the base case increase over time as motorists switch to more efficient vehicles to reduce exposure to higher fuel costs.

**Table 3B-1. Gasoline Demand Reductions from Pay-at-the Pump Auto Insurance**

	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	614	743	885
Reduction From Base Case Demand (percent)	3.58	3.81	3.95

\*Gasoline displacement.

Table 3B-2 shows the net-benefit results for consumers and the impact on government revenues (assumed to be zero in this case) in present value terms, for 2010, 2020, and 2030, for a 5 percent discount rate. These calculations are net amounts relative to the base case forecast.

The gain in economic efficiency that would be predicted by economic theory is reflected in the positive net benefits for consumers shown in the table. These benefits are a net of the reduction in direct payments to insurance companies and the burden of higher fuel costs. The average motorist now incorporates accident risk in his marginal driving decisions and is able to reduce his total cost of insurance by driving less—an option not available without PATP.

The sum of these two impacts (the same as consumer benefits since there is no net effect on government revenues) is shown as “Non-Environmental Direct Benefits” in Table 3B-2, and represents direct benefits excluding the “external” beneficial effects of reduced driving and gasoline demand (e.g., less congestion, less gasoline-related pollution).

Although gasoline demand falls, the reduction in gasoline excise tax revenues is not included as an impact on government revenues in this case. It is assumed that required highway expenditures (funded in part by gasoline taxes) are roughly proportional to VMT, so that the reduction in driving brought about by the gasoline surcharge decreases the costs of highway service and maintenance.<sup>3</sup> Thus, less revenue is required for these purposes, and the reduction in required revenue is assumed to be approximately the same as the loss in excise taxes.

**Table 3B-2. Present Value (2002 Benchmark, 5% Discount Rate) of Direct Net Benefits of Pay-at-the-Pump Relative to Base Case Forecast (million 2001\$)**

<b>Time Period</b>	<b>Net Consumer Benefits (A)</b>	<b>Government Revenues (B)</b>	<b>Non-Environmental Net Direct Benefits (A+B)</b>
2002-2010	520	--	520
2002-2020	1,009	--	1,009
2002-2030	1,357	--	1,357

### Key Drivers and Uncertainties

The responsiveness of motorists to higher fuel prices will determine net consumer benefits. It should be noted that the price elasticity of gasoline demand (that is, the percent change in gasoline demand due to a one percent change in the cost of gasoline per gallon) endogenous to the CALCARS model is consistent with most other empirical work. However, if we assume all motorists carry minimum insurance in the base case forecast, consumer net benefits will always be positive, given the assumptions made here (they would be zero if there were absolutely no response to higher gasoline prices).

If we allow for the possibility that there would continue to be a significant number of uninsured drivers in California without PATP, it is likely that a PATP system would have even more favorable welfare impacts for insured motorists. The fuel surcharge would force uninsured drivers to pay at least some of the costs that they impose on the insured. The current charge for uninsured motorist coverage that is part of liability insurance could then be reduced or eliminated. On the other hand, such a system would have adverse welfare impacts on many uninsured drivers.

<sup>1</sup> See, for example, Sugarman, S.D. (1994): “*Pay at the Pump*” *Auto Insurance: The California Vehicle Injury Plan (VIP)*. Berkeley: Institute of Governmental Studies Press, University of California.

<sup>2</sup> Insurance companies do currently charge higher premiums for relatively high-VMT drivers to some extent. However, the steps over which the premium remains constant are extremely wide. In addition, insurance companies have no way of ensuring higher premiums for such drivers, since they have to depend on the insured to report estimated miles traveled.

<sup>3</sup> Staff used a study by the California Department of Transportation called the *Highway Cost Allocation Study* (California Department of Transportation, 1987) to estimate the relative cost attributable to highway expenditures by vehicle type. It was estimated that around 73 percent of total maintenance costs can be attributed to car and light truck vehicle miles traveled.

## **Option 3C**

### **Tax on Vehicle Miles Traveled**

**(Analysis by Chris Kavalec)**

#### **Description**

This option looks at the effect of implementing a tax on vehicle miles traveled (VMT) in California of 2 cents per mile for the period 2003-2020.

#### **Background**

A tax on VMT would reduce driving and therefore gasoline demand. However, unlike a higher tax imposed on gasoline, a VMT tax does not create an incentive to switch to a more fuel efficient vehicle to reduce exposure to the tax. In this sense, then, such a tax is less effective in reducing gasoline demand than a higher gasoline tax.

An obvious hurdle to implementing a VMT tax is collection. A system would have to be developed to collect the fees in as unobtrusive a manner as possible while minimizing possible fraud. Such a tax would likely have to be collected more than once a year so that motorists make the connection between driving and a higher cost of driving; an annual collection might make the connection too remote.

#### **Assumptions and Methodology**

The Commission's CALCARS model was used to simulate this option. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

The per-mile cost of driving was increased by 2 cents, and this increase affected annual miles driven as well as vehicle demand.<sup>1</sup> Vehicle choice was not affected since the per-mile fee would be the same no matter what type of vehicle was chosen (unlike a higher gasoline tax). The VMT tax was assumed to affect personal vehicles only, as the models used by the Commission for commercial fleet and freight energy demand are currently not behaviorally based.

Revenues from the tax would presumably provide a benefit to California in some form (perhaps through a rebate or a reduction in another type of state tax) and are therefore shown as a benefit in Table 3C-2.

#### **Results**

Table 3C-1 shows the projected reductions in gasoline demand for the years 2010, 2020, and 2030 in California, in both absolute and percentage terms. Unlike the higher gasoline tax option (Option 3A), the annual percentage decrease in gasoline demand is projected to remain relatively constant, since the VMT tax creates no incentive to purchase a more fuel efficient vehicle.

**Table 3C-1. Gasoline Demand Reductions from 2 Cent VMT Tax**

	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	490	554	631
Reduction From Base Case Demand (percent)	2.84	2.82	2.82

\*Gasoline displacement.

Table 3C-2 shows the net benefit results for consumers and the impact on government revenues (in this case a positive net benefit), in present value terms, for 2010, 2020, and 2030, for a 5 percent discount rate. These calculations are net amounts relative to the base case forecast. The negative consumer benefits (also known as the change in consumer surplus) are equal to the higher cost per mile times the new (lower) level of VMT, plus the lost benefits to motorists due to reduced driving (known as the “deadweight” loss to society). The state government sees a large increase in revenues, which is counted as a positive net benefit. The sum of these two impacts is shown as “Non-Environmental Direct Benefits” in Table 3C-2, and represents direct benefits excluding the “external” beneficial effects of reduced driving and gasoline demand (e.g., less congestion, less gasoline-related pollution). These entries are negative, reflecting this deadweight loss.<sup>2</sup> However, once environmental effects are considered, total direct benefits may be positive.

Although gasoline demand falls, the reduction in gasoline excise tax revenues is not included as part of the impact on government revenues in this case. It is assumed that required highway expenditures (funded in part by gasoline taxes) are roughly proportional to VMT, so that the reduction in driving brought about by the VMT tax decreases the costs of highway service and maintenance.<sup>3</sup> Thus less revenue is required for these purposes, and the reduction in required revenue is assumed to be approximately the same as the loss in excise taxes.

**Table 3C-2. Present Value (2002 Benchmark, 5% Discount Rate) of Direct Net Benefits of 2 Cent VMT Tax Relative to Base Forecast (million 2001\$)**

Time Period	Net Consumer Benefits (A)	Government Revenues (B)	Non-Environmental Net Direct Benefits (A+B)
2002-2010	-32,560	31,932	-628
2002-2020	-62,868	61,673	-1,195
2002-2030	-84,295	82,702	-1,593

### Key Drivers and Uncertainties

The key driver for the results described above is the response by households to driving costs predicted by the CALCARS model. It should be noted that the price elasticity of vehicle miles traveled (that is, the percent change in VMT due to a one percent change in driving cost per mile) endogenous to the model is consistent with most other empirical work.

<sup>1</sup> The choice of 2 cents per mile was somewhat arbitrary—an amount that promised to have a significant effect on gasoline demand but not so high as to create an onerous financial burden for motorists.

---

<sup>2</sup> The higher cost of driving per mile times the new VMT is equal to the increase in government revenue. The net loss to consumers therefore exceeds the gain in revenue by the amount of the deadweight loss.

<sup>3</sup> Staff used a study by the California Department of Transportation called the ***Highway Cost Allocation Study*** (California Department of Transportation, 1987) to estimate the relative cost attributable to highway expenditures by vehicle type. It was estimated that around 73 percent of total maintenance costs can be attributed to car and light truck vehicle miles traveled.

## **Option 3D Feebates (Analysis by Chris Kavalec)**

### **Description**

This analysis looks at the effect of implementing a system of fees and rebates (“feebates”) in California for 2003-2030 for new light-duty vehicles to encourage the purchase of more efficient vehicles. The analysis examines two cases. The first case includes a feebate program for California only (State feebate), which includes a “limited” response (in terms of adding additional fuel economy technologies to new cars and light trucks) by auto manufacturers. The second case includes a nationwide feebate system, with a “full” response by manufacturers.

### **Background**

Feebates are a combination of fees and rebates. Feebates are targeted to the sale of new personal vehicles, based on fuel efficiency or emissions of carbon; the analysis presented here examines the effects of a feebate system based on carbon emissions. Vehicles emitting relatively low levels of carbon receive rebates while their high carbon emitting counterparts pay fees. Such a feebate system is also a means of improving fleet average fuel efficiency and therefore reducing overall gasoline consumption, since low-mileage gasoline vehicles emit more carbon per mile.

For this analysis, feebates are structured so that the net feebate receipts of the government are zero; that is, to achieve “revenue neutrality.” The fees paid to the government exactly offset the rebates paid by the government on the sales of favored vehicles. The feebate system has a zero point, or “carbon threshold.” The threshold is the carbon emissions level at which vehicle purchasers neither receive a rebate nor pay a fee. Those that exceed the threshold, high-carbon vehicles, pay a fee to government. The revenues are used to provide a rebate to those who buy a vehicle that emits below the threshold, a low-carbon vehicle.

Feebates were originally proposed by Gordon and Levenson at Lawrence Berkeley Laboratory in 1989.<sup>1</sup> This proposal was termed “DRIVE+” (**D**emand based **R**eduction **I**n **V**ehicle **E**missions **plus** reductions in carbon dioxide) and was developed for possible use in the state of California. Legislation based on the DRIVE+ proposal (and going by the same name) was introduced in the California legislature in 1990. Both houses passed the bill but it was vetoed by then-Governor Deukmejian. It has been reintroduced several times since then but has never become law. The DRIVE+ proposal was based on tailpipe emissions and emissions of carbon dioxide.

Several versions of feebates have also been proposed at the federal level. This continued interest seems to be based on the twin notions that as a market-based policy, feebates can reduce gasoline demand with a minimum amount of economic distortion, and that the revenue neutrality capability of feebates make such proposals more palatable politically than other more costly programs with similar aims.

The revenue neutrality of feebates has political and administrative appeal. However, it is obvious that some consumers would lose and some would gain economically. In contrast to the government revenue neutrality, the net of the losses and gains by consumers may not be equal to zero.

This analysis assumes that there is some response by auto manufacturers to the feebate. In other words, manufacturers are induced to increase the fuel efficiency of at least some models, as the feebate makes this a more profitable strategy.<sup>2</sup> This response is much more pronounced in the nationwide feebate case, where almost all models are affected, than in the State feebate case. This is discussed further in “Assumptions and Methodology,” below.

For purposes of this analysis, feebates affect consumer welfare in four ways.<sup>3</sup> First, feebates act as a system of taxes and subsidies, which create what economists call a “deadweight” loss to society.<sup>4</sup> Second, the average vehicle owner benefits from reduced expenditures on gasoline. Third, the installation of additional fuel economy technologies by automakers increases the average price of new vehicles (although those receiving a rebate would still pay less than before). Fourth, the increased fuel efficiency offered by manufacturers typically comes at the expense of vehicle performance (represented in the CALCARS model by acceleration and top speed), although this is not always the case.

This analysis looks at feebates under two scenarios. Case 1 assumes a State feebate with a limited response by automakers, as described in the following section. Case 2 assumes a nationwide system where manufacturers are induced to add fuel economy technologies to almost all models. In a sense, these two cases serve to “bound” the impacts of feebates.

### **Assumptions and Methodology**

The Commission’s CALCARS model was used to simulate these options. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts consumer vehicle choice at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

The feebate rate used in this analysis is \$30,000 per pound of carbon per mile.<sup>5</sup> As an example, using a carbon threshold corresponding to 21 miles per gallon (mpg), the fee for a new light-duty vehicle (LDV) with an efficiency of 15 mpg would be around \$3,500, while the rebate paid to the purchaser of a 30-mpg LDV would be roughly \$2,600. The threshold level in each year resulted from an iteration process that continued until revenue neutrality was achieved.

For Case 1 (State feebate), manufacturers were assumed to install additional fuel economy technologies for models whose sales in California exceeded 20,000 in 2001.<sup>6</sup> For these models, technologies were added in the same manner as in the nationwide case (see below). In the CALCARS simulation, which predicts ownership at the size class level, vehicle class characteristics (e.g., fuel efficiency, acceleration) were then changed from those in the base case, based on the proportion of sales in that class attributable to such models.<sup>7</sup>

For Case 2 (nationwide feebate), vehicle manufacturers were assumed to install additional fuel economy technologies as long as the cost of these technologies was less than the change in the feebate resulting from these additions. These changes in vehicle attributes were projected from analysis performed by K.G. Duleep (EEA, Inc.) for a nationwide feebate scenario. The methodology used by Duleep also allowed manufacturers to trade excess credits.

Feebates are assumed to affect personal vehicles only, as the models used by the Commission for commercial fleet and freight energy demand are currently not behaviorally based.

All other assumptions are identical to those made in the base case forecast.

## Results

**Case 1: State Feebate.** Table 3D-1 shows the projected reductions in gasoline demand in the case of a State feebate (limited manufacturer response) for the years 2010, 2020, and 2030 in California, in both absolute and percentage terms. In the simulation, average fuel efficiency for new cars reaches 31.1 mpg by 2010 and 32.8 mpg by 2020, compared to 29.8 mpg and 30.1 mpg, respectively, in the base case. For light trucks, the corresponding numbers are 21.5 mpg and 22.6 mpg (compared to 20.4 mpg and 20.7 mpg). Annual reductions in gasoline demand relative to the base case increase over time as more and more of the total LDV fleet in California is affected.

**Table 3D-1. Gasoline Demand Reductions from State Feebate**

	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	389	1,023	1,429
Reduction From Base Case Demand (percent)	2.3	5.2	6.4

\*Gasoline displacement relative to base case.

Table 3D-2 shows the net-benefit results for consumers and the impact on government revenues for 2010, 2020, and 2030. These calculations are net amounts relative to the base case forecast.

Due to manufacturer response, net consumer benefits include both monetary and non-monetary impacts. The monetary impacts are the net of the effects of the change in vehicle purchase prices (including the deadweight loss described above) and the private benefits of reduced fuel consumption. The non-monetary category includes the impact of manufacturer response on vehicle performance due to the feebate. For most years, increased fuel efficiency comes at the expense of vehicle performance (acceleration and top speed) relative to the base case values. In later years, however, the fuel economy technologies installed actually improve vehicle performance (e.g., variable valve timing).

The total change in consumer surplus is positive; the benefits of reduced fuel consumption outweigh the cumulative effects of higher average vehicle prices, the deadweight loss, and the degradation (in most years) in vehicle performance.

The negative entries for government revenues represent the reduction in gasoline excise taxes (less gasoline sold) collected relative to the base case forecast. Net direct benefits (non-

environmental) are calculated by summing net consumer benefits and the impact on government revenues.

**Table 3D-2. Present Value (2002 Benchmark, 5 Percent Discount Rate) of Direct Net Benefits of State Feebate Relative to Base Case Forecast (million 2001\$)**

	Net Consumer Benefits (Change in Consumer Surplus) (A)		Government Revenues (B)	Non- Environmental Direct Benefits (A+B)
Time Period	Monetary*	Non-Monetary**		
2002-2010	388	-134	-412	-158
2002-2020	3,405	-152	-1,741	1,512
2002-2030	8,211	354	-3,194	5,371

\* The net of the increase in average vehicle cost, the private benefits of reduced fuel consumption, and the deadweight loss.

\*\* Includes the impact of the feebate and manufacturer response on vehicle performance.

**Case 2: Nationwide Feebate.** Table 3D-3 shows the projected reductions in gasoline demand in the case of a nationwide feebate (full manufacturer response) for the years 2010, 2020, and 2030 in California, in both absolute and percentage terms. Due to the additional fuel economy technologies being installed on a much more widespread basis, gasoline demand reductions are much more significant than in the State feebate case. In the simulation, average fuel efficiency for new cars reaches 35.0 mpg by 2010 and 41.9 mpg by 2020, compared to 29.8 mpg and 30.1 mpg, respectively, in the base case. For light trucks, the corresponding numbers are 24.3 mpg and 28.5 mpg (compared to 20.4 mpg and 20.7 mpg). As in the previous feebate case, annual reductions in gasoline demand relative to the base case increase over time as more and more of the total LDV fleet in California is affected.

**Table 3D-3. Gasoline Demand Reductions from Nationwide Feebate**

	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	979	2,929	4,259
Reduction From Base Case Demand (percent)	5.71	15.01	19.01

\*Gasoline displacement relative to base case.

Table 3D-4 shows the net-benefit results for consumers and the impact on government revenues for 2010, 2020, and 2030. These calculations are net amounts relative to the base case forecast.

As in Case 1, net consumer benefits include both monetary and non-monetary impacts, defined as above. Also as in Case 1, increased fuel efficiency comes at the expense of vehicle performance (acceleration and top speed) relative to the base case values in the early years, while the opposite is true in the later years.

The total impact on consumers (the total change in consumer surplus) is positive and much more significant than in Case 1, due to the more extensive placement of fuel economy technologies by manufacturers. The negative entries for government revenues represent the reduction in gasoline

excise taxes (less gasoline sold) collected relative to the base case forecast. Non-environmental direct benefits are calculated by summing net consumer benefits and the impact on government revenues.

**Table 3D-4. Present Value (2002 Benchmark, 5 Percent Discount Rate) of Direct Net Benefits of Nationwide Feebates Relative to Base Case Forecast (million 2001\$)**

	Net Consumer Benefits (Change in Consumer Surplus) (A)		Government Revenues (B)	Non- Environmental Direct Benefits (A+B)
Time Period	Monetary <sup>*</sup>	Non-Monetary <sup>**</sup>		
2002-2010	2,653	-572	-1,007	1,074
2002-2020	15,605	-846	-4,662	10,097
2002-2030	33,256	890	-8,925	25,221

<sup>\*</sup> The net of the increase in average vehicle cost, the private benefits of reduced fuel consumption, and the deadweight loss.

<sup>\*\*</sup> Includes the impact of the feebate and manufacturer response on vehicle performance.

### Key Drivers and Uncertainties

Given the assumptions made in this analysis, the impacts of a feebate system, both in terms of the reduction in gasoline demand and on the benefits to California vehicle owners, depend heavily on the degree to which auto manufacturers respond. In fact, without any manufacturer response, net consumer benefits may be negative over all time periods, due to the deadweight loss.<sup>8</sup> Therefore, any feebate plan must carefully consider the reaction of automakers.

Of the two cases, nationwide feebates appear to yield the highest direct benefits for California; however, State feebates also appear promising (although net direct benefits are slightly negative in the first few years of the simulation) if manufacturers respond in a limited fashion as assumed for Case 1.

It should be acknowledged here that any analysis (including the work of K.G. Duleep) designed to estimate the response by automakers to a nationwide feebate, as well as, the cost and effectiveness of installing additional fuel economy technologies, requires engineering and economic judgement, particularly in predicting the impact of combining technologies.

<sup>1</sup> Gordon, D., and L. Levinson, "DRIVE+: A Proposal for California to use Consumer Fees and Rebates to Reduce New Motor Vehicle Emissions and Fuel Consumption", Lawrence Berkeley Laboratory, Berkeley, CA, 1989.

<sup>2</sup> When the addition of a technology to improve fuel efficiency costs less to a manufacturer than the resulting impact on the feebate, the manufacturer can increase profits by adding the technology.

<sup>3</sup> There may well be effects not captured here; for example, vehicle weight reductions. In providing a revised set of vehicle attributes for this analysis, K.G. Duleep assumed that the feebate induces manufacturers to reduce slightly the weight of some models to improve fuel efficiency, and weight is not included as a vehicle characteristic in CALCARs. Therefore, to the extent that vehicle owners value weight as an attribute, the estimated net benefits of a feebate may be overstated. As another example, manufacturer efforts to improve fuel economy may involve the use of composite materials that can potentially prolong the life of a vehicle.

---

<sup>4</sup> Intuitively, those who switch from a high-carbon to a low-carbon vehicle will not benefit by the full amount of the rebate, since the value to these buyers of the high-carbon vehicle was higher than that of the low-carbon vehicle before the feebate was implemented (see the discussion on the net costs of vehicle incentives in the appendix). In other words, the average buyer who switches to the low-carbon vehicle reaps a benefit less than the amount lost by the high-carbon buyer who provided the rebate. All else equal, when the losses and gains are summed over all new vehicle buyers, the net impact on benefits is negative.

<sup>5</sup> \$30,000 is a somewhat arbitrary figure, high enough to have a significant effect on vehicle prices and therefore vehicle purchases. It was used in a previous study by Commission staff that compared the effects of a carbon tax and a feebate that were designed to yield the same reduction in gasoline demand (“A Comparison of Statewide Policies to Reduce Carbon Emissions by Personal Cars and Light-Duty Trucks in California: Carbon Taxes vs. Feebates”, October, 1996).

<sup>6</sup> According to K.G. Duleep, if sales of a particular model exceed 20,000 vehicles in a certain area, the manufacturer would likely find it profitable to add fuel economy technologies if faced with a feebate, thus providing a “California version” of the model.

<sup>7</sup> For example, if 50 percent of the sales in a particular class were attributable to models selling more than 20,000 units in 2001, the appropriate vehicle characteristics were changed in each year to the base case values plus 50 percent of the difference between the base case attributes and the national feebate case attributes. The percentage of vehicles in a given class attributable to these models ranged from zero (various classes) to over 80 (the standard pickup class).

<sup>8</sup> This result was indeed found in a previous analysis of feebates (“A Comparison of Statewide Policies to Reduce Carbon Emissions by Personal Cars and Light-Duty Trucks in California: Carbon Taxes vs. Feebates,” CEC Staff Report, October, 1996).

## **Option 3E**

### **Registration Fee Transfer**

**(Analysis by Chris Kavalec)**

#### **Description**

This option would transfer a portion of annual auto registration fees in California (for 2003-2030) to a marginal cost through a gasoline surcharge.

#### **Background**

Economic efficiency and consumer welfare can be improved if the cost of providing a service can be more closely tied to the actual users of that service. Since a portion of annual auto registration fees are directed toward transportation uses, benefits may be realized by converting this portion into a fuel surcharge. This would mean that those that drive more, all else equal, would pay more toward funding our transportation system, while those that drive less would pay less.

Because a registration fee transfer would increase the marginal cost of driving through the fuel surcharge, VMT and gasoline use should decrease. Therefore, the transfer acts as a travel demand measure, and external costs related to both driving (e.g., congestion) and gasoline use (e.g., global warming) would be expected to fall. An advantage of a transfer relative to other measures (such as a VMT tax) is that private costs for the *average* motorist may be reduced.

#### **Assumptions and Methodology**

The Commission's CALCARS model was used to simulate this option. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

In this analysis, a portion (\$50) of current registration fees is converted into a fuel surcharge. Fifty dollars was roughly the amount of fees per average vehicle directed toward the California Highway Patrol and state highway maintenance and construction in 2000. (per *Fast Facts*, from the Department of Motor Vehicles).<sup>1</sup> This portion is equal to 0.4 cents per mile (assuming average annual mileage of 12,000). To collect this amount per mile required a fuel surcharge of slightly less than 10 cents per gallon. For this option, therefore, vehicle owners would pay \$50 less per year in registration fees while paying an increase in the cost of gasoline of around ten cents per gallon.

Note that the critical assumption that must be made is that the cost of the Highway Patrol and of state highway construction and maintenance is proportional to vehicle miles traveled.

The registration fee transfer was assumed to affect personal vehicles only, as the models used by the Commission for commercial fleet and freight energy demand are currently not behaviorally based.

All other assumptions are identical to those made in the base case forecast.

## Results

Table 3E-1 shows the projected reductions in gasoline demand for the years 2010, 2020, and 2030 in California, in both absolute and percentage terms. Similar to the gasoline tax analysis, annual reductions in gasoline demand relative to the base case increase over time as motorists switch to more efficient vehicle to reduce exposure to higher fuel costs.

**Table 3E-1. Gasoline Demand Reductions from Registration Fee Transfer**

	Annual Gasoline Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	120	145	172
Reduction From Base Case Demand (percent)	0.70	0.74	0.77

\*Gasoline displacement.

Table 3E-2 shows the net-benefit results for consumers and the impact on government revenues (assumed to be zero in the this case) in present value terms, for 2010, 2020, and 2030, for two discount rates. These calculations are net amounts relative to the base case forecast.

The gain in economic efficiency that would be predicted by theory is reflected in the positive net benefits for consumers shown in the table. These benefits are a net of the reduction in direct payments for registration fees and the burden of higher fuel costs. Effectively, the average motorist now incorporates highway costs in his marginal driving decisions and is able to reduce his total costs by driving less—an option not available without a registration fee transfer.

The sum of these two impacts (the same as consumer benefits since there is no net effect on government revenues) is shown as “Non-Environmental Direct Benefits” in Table 3E-2, and represents direct benefits excluding the “external” beneficial effects of reduced driving and gasoline demand (e.g., less congestion, less gasoline-related pollution).

Although gasoline demand falls, the reduction in gasoline excise tax revenues is not included as an impact on government revenues in this case. It is assumed that required highway expenditures (funded in part by gasoline taxes) are roughly proportional to VMT, so that the reduction in driving brought about by the VMT tax decreases the costs of highway service and maintenance.<sup>2</sup> Thus less revenue is required for these purposes, and the reduction in required revenue is assumed to be approximately the same as the loss in excise taxes.

**Table 3E-2. Present Value (2002 Benchmark, 5% Discount Rate) of Direct Net Benefits of Registration Fee Transfer Relative to Base Case Forecast (million 2001\$)**

<b>Time Period</b>	<b>Net Consumer Benefits (A)</b>	<b>Government Revenues (B)</b>	<b>Non-Environmental Net Direct Benefits (A+B)</b>
2002-2010	21	--	21
2002-2020	40	--	40
2002-2030	54	--	54

### **Key Drivers and Uncertainties**

The responsiveness of motorists to higher fuel prices will determine net consumer benefits. It should be noted that the price elasticity of gasoline demand (that is, the percent change in gasoline demand due to a one percent change in the cost of gasoline per gallon) endogenous to the CALCARS model is consistent with most other empirical work. However, consumer net benefits will always be positive, given the assumptions made here (they would be zero if there was no response to higher gasoline prices).

---

<sup>1</sup> *Fast Facts*, Department of Motor Vehicles, 2001.

<sup>2</sup> Staff used a study by the California Department of Transportation called the *Highway Cost Allocation Study* (California Department of Transportation, 1987) to estimate the relative cost attributable to highway expenditures by vehicle type. It was estimated that around 73 percent of total maintenance costs can be attributed to car and light truck vehicle miles traveled.

## **Option 3F**

### **Purchase Incentives for Efficient Vehicles**

**(Analysis by David Ashuckian and Dan Fong)**

#### **Description**

This option involves government providing a purchase incentive for the most fuel-efficient vehicles in each class at the time of sale to reduce the purchase price and thus, increase the relative value of fuel-efficient vehicles compared to average fuel economy vehicles.

#### **Background**

Incentives are provided to consumers to encourage the purchase of specific products. Consumer incentives can be provided in the form of tax credits or deductions, rebates and the related fees, or cash incentives directly to the consumer at the time of purchase, or to the manufacturer before the sale.

Direct consumer incentives are a means to increase the market share of fuel-efficient vehicle technologies. The direct consumer incentive approach, unlike a tax credit, is not determined by the income of the purchaser. The incentive can be obtained even if the purchaser does not have taxable income. These various forms of incentives have at least one commonality – the funding source is tax based and as such they reduce or return taxes paid by consumers.

Efficient vehicle products currently available on the market have the potential to reduce California's gasoline demand by up to 3 billion gallons per year. This level of fuel savings would be achieved if all vehicles purchased each year had the same fuel economy as the "best-in-class" vehicle in terms of fuel economy.

#### **Assumptions and Methodology**

The average vehicle mileage calculated from all models in the United States Environmental Protection Agency Fuel Economy Guide for Model Year 2002 passenger cars and light-duty trucks is 21 miles per gallon.<sup>1</sup> Based on these vehicles available, the most efficient vehicle in-class is approximately 28 percent more efficient than the average of all vehicles available. If consumers purchased the most efficient vehicles in each class, the average fuel economy of vehicles operating in California would increase from approximately 21 to 27 miles per gallon.

Today, over 1.5 million new vehicles are sold each year in California. Consumer market research conducted by Roland Berger Strategy Consultants indicates that consumers are willing to pay approximately 10 percent more for a vehicle that has an improved fuel economy.<sup>2</sup>

Assuming an incentive program could increase the purchase of the most fuel-efficient vehicles, this scenario assumes that a 10 percent purchase incentive would result in 10 percent additional vehicle sales per year.

At the current fleet growth rate of 2 percent per year as calculated from Department of Motor Vehicle Registration data, staff calculates that with an increase in efficient vehicles purchases of 10 percent by 2010, approximately 1.4 million additional vehicles would be achieving this higher fuel economy.<sup>3</sup> At an average rate of 12,500 miles traveled per year, this increase in fuel economy from these 1.4 million vehicles could result in fuel savings of 225 million gallons in 2010.

**Cost.** Using Department of Energy data for vehicle prices, staff calculated the average price for the most efficient vehicle in class is estimated to be \$2,400 less than a comparable vehicle.<sup>4</sup> This scenario assumes that in addition to the lower average vehicle cost, a consumer would need an additional \$1,500 incentive in order to purchase the more efficient vehicle.

## Results

**Table 3F-1. Petroleum Fuel Reductions from Purchase Incentives for Efficient Vehicles**

	Annual Petroleum Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	225	527	896
Reduction From Base Case Demand (percent)	1.3	2.7	4.0

\*Gasoline displacement.

**Table 3F-2. Present Value (2002 Benchmark, Discount Rate 5%) of Direct Net Benefits for Purchase Incentives for Efficient Vehicles (2001\$)**

Time Period	Net Consumer Benefits (A)	Government Expenditures (B)	Non-Environmental Direct Benefits (A+B)
2002-2010	6,139	2,221	3,917
2002-2020	13,421	4,702	8,720
2002-2030	20,246	6,953	13,293

## Key Drivers and Uncertainties

There is uncertainty in the number of people who would have purchased the vehicle without the incentive and there is uncertainty in the number of people who will change their purchase habit for the incentive amount. There is also uncertainty in the projected fuel savings for each vehicle class in future years as the fuel savings is directly attributable to the fuel economy of the vehicle models offered.

<sup>1</sup> Department of Energy Model Year 2002 Fuel Economy Guide, DOE/EE-0250.

<sup>2</sup> "Automotive Hybrids: A Desired Vehicle for the Right Price" Roland Berger, Mahesh Lunani, Roland Berger Strategy Consultants. October 2001.

<sup>3</sup> California Department of Motor Vehicle Registration Data, 2001

<sup>4</sup> Department of Energy retail price data for model year 2002, [www.fueleconomy.gov](http://www.fueleconomy.gov)

**GROUP 4**  
**OTHER OPTIONS**

## **Option 4A**

### **Expanded Use of Public Transit**

**(Analysis by Leigh Stamets)**

#### **Description**

Increased transit use would reduce growth in vehicle miles traveled and petroleum use. This option involves additional state and federal funding to achieve expanded use of transit.

#### **Background**

Transit accounts for about 1 percent of the passenger miles of travel in the state. Buses support about two-thirds of transit travel with light and heavy rail providing the remainder. Transit serves as a reasonably energy efficient mode of travel. With an average of about 10 passengers per vehicle, buses achieve nearly 40 passenger miles per equivalent gallon of diesel fuel. Rail averages about 3 passenger miles per kilowatt hour. Delucchi estimates the social costs per passenger mile of transit are likely several times the comparable costs for autos.<sup>1</sup> The government subsidies required for operating and capital costs account for most of this cost.

In addition to reducing petroleum demand, expanded use of transit helps reduce auto use and congestion. Analysis by NRDC shows household VMT strongly depends on access to transit and housing density.<sup>2</sup> Testimony by the Planning and Conservation League (PCL) noted that a recent study found that in a transit-oriented neighborhood people walked, biked, and took public transit for 40 percent of daily trips, as opposed to less than 15 percent for the general region.<sup>3</sup> The PCL has proposed the Traffic Congestion Relief Act that would allocate 30 percent of the state share of the sales tax on new and used cars and trucks to a new trust fund for transportation improvements around the state. Dedicated programs in the Act would include building new light rail and bus services to reduce traffic congestion in every region and provide operating funds for transit.

#### **Assumptions and Methodology**

The transit portion of passenger miles traveled in the state today is about 30 percent less than in 1980. Although since 1980 ridership on rail transit has increased, bus transit accounts for about 70 percent of the transit ridership and bus ridership has stayed nearly constant during the last 20 years.<sup>4</sup> A strategy, for example, consisting of a series of programs to increase transit use from 1 percent to 2 percent of passenger travel in the state by 2020 would save approximately 192 million gallons of petroleum fuel assuming the additional transit service was provided by rail or natural gas buses. This strategy would require transit ridership to grow at an average annual rate of 5.4 percent. Using 1.6 passengers per light-duty vehicle mile, 1 percent of passenger travel equals 4 billion vehicle miles or 6.4 billion passenger-miles. This travel would require 192 million gallons of gasoline using vehicles with an average fuel economy of 21 miles per gallon (base case forecast). The same average growth rate of 5.4 percent in transit ridership through 2030 would increase transit use to 2.8 percent of passenger travel and save 411 million gallons of gasoline. As various transportation factors such as mitigating congestion dominate the

development of transit, we have not identified any particular transit expansion or the associated project costs.

## Results

	Annual Petroleum Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	N/A	192	411
Reduction From Base Case Demand (percent)	N/A	0.8	1.5

\*Gasoline displacement.

## Key Drivers and Uncertainties

- Appropriate land use planning to enhance transit use.
- Adequate availability of funds to enhance transit service.
- Cost-effectiveness of enhanced transit to reduce petroleum use.

---

<sup>1</sup> Delucchi, Mark, *Should We Try to Get the Prices Right?* ACCESS, University of California Transportation Center, Berkeley, CA, Spring 2000.

<sup>2</sup> Liu, Donna, Natural Resources Defense Council, CEC Workshop, September 18, 2001.

<sup>3</sup> Spelliscy, Sandra, Planning and Conservation League, CEC Workshop, September 18, 2001.

<sup>4</sup> Travel and Related Factors in California, California Department of Transportation, Annual Summary 1981 and 1998.

## **Option 4B Land Use Planning (Analysis by Leigh Stamets)**

### **Description**

Housing density, job-housing balance and other land use factors affect VMT and transportation energy use. This option would enact legislation to provide guidance and economic incentives to achieve improved land use to reduce VMT growth.

### **Background**

Based on analysis by Parsons Brinckerhoff, California could reduce statewide transportation energy consumption by 3-10 percent with the implementation of Smart Growth policies across the state.<sup>1</sup> The estimates are extrapolated from Smart Growth travel modeling efforts in five California regions: Los Angeles (Western Riverside County only), San Francisco, San Diego, Sacramento and Monterey. The estimates reflect four Smart Growth Actions:

- City and transit station-focused land use development
- Increases in transit supply
- Market pricing (parking fees)
- Improvements to regional job-housing balance

Vehicle Miles Traveled (VMT) has a direct correlation with transportation energy consumption. Smart Growth VMT savings for city-centered land use development ranged from: 0.2 percent (Riverside) to 11 percent (Sacramento) and 12.2 percent (Monterey). Scenarios for transit station-focused development typically combined with some level of increased transit supply, reducing VMT by 1.7 percent (Riverside) to 13.0 percent (San Diego). San Francisco (MTC) runs implied pricing leads to a 0.8 percent travel reduction. Improvement of jobs-housing balance in Riverside (28 percent increase in jobs/household ratio) leads to a 1.6 percent reduction in daily travel.

California has several opportunities to assist regional and local entities in educating the populace and facilitating sustainable Smart Growth choices. Some relevant existing and ongoing California legislation which could help support strategies to enhance land use planning include:

AB 210 (Katz)-- This law enables a limited employer parking “cash-out” policy. That is, offering employees who receive free parking the choice of using the parking or receiving the equivalent value in cash.

AB 2140 (Keeley)-- This law supports MPOs in assessing the effects of Smart Growth planning, as an alternate to current 20-year regional transportation plan projections. Since Smart Growth concepts run counter to current trends, education of government and the public as to the regional benefits of such policies, facilitated by this bill will be valuable. MPOs should be encouraged to

educate the public about the consequences of existing trends, potential benefits of Smart Growth policies, and the involve the public in decisions about how the region should grow.

AB 680 (Steinburg)-- This bill proposes to restructure retail taxation policies to encourage more market-driven retail location decisions. Localities compete over new retail and suburbs have historically won over central city locations. A more market-driven location decision would scatter retail closer to residential demand, leading to shorter retail trips, and associated travel reduction and energy benefits.

### **Assumptions and Methodology**

As land use planning is a long-term strategy, Parsons Brinckerhoff developed the estimates of potential energy savings of land use measures only for 2020. Staff assumed only limited additional savings would be achieved by 2010. The estimate of 3 percent transportation energy savings would reduce gasoline demand by 580 million gallons and 10 percent savings would reduce gasoline demand by 1,920 million gallons by 2020. The graph shows the fuel savings if statewide VMT were reduced by 3 percent after 2020. As land use measures cause a number of trade-offs for costs and benefits, no attempt was made to calculate direct net benefits.

### **Results**

	<b>Annual Petroleum Reduction</b>		
	<b>2010</b>	<b>2020</b>	<b>2030</b>
Strategy Results (millions of gallons)*	N/A	580	680
Reduction From Base Case Demand (percent)	N/A	2.4	2.5

\*Gasoline displacement.

### **Key Drivers and Uncertainties**

- Resistance to changing present patterns of urban growth.
- Lack of understanding of advantages of “smart growth”.
- Need for enlightened long term planning.

---

<sup>1</sup> California Smart Growth Energy Savings MPO Survey Findings, Parsons Brinkerhoff, September 21, 2001.

## **Option 4C**

### **Telecommuting**

**(Analysis by Leigh Stamets)**

#### **Description**

Telecommuting is salaried employees working at home or a location closer to home than the regular workplace, using information and communication technology to support productivity and communication with other workers and clients. Intuitively it seems steps to increase telecommuting would reduce VMT and transportation energy use. Public agencies could increase case-study information on successful telecommuting programs or increase incentives to increase telecommuting.

#### **Background**

Telecommuting is a potential strategy for reducing travel and hence congestion and energy consumption, as well as improving air quality. Telecommuting appears to have considerable popular appeal, offering employees reduced commuting time and cost while offering employers the potential of improved productivity and savings of facilities costs. On the other hand, a number of barriers prevent telecommuting from achieving the penetration that might be expected. On the employer side, conventional wisdom holds that management resistance to the concept is probably the largest single factor slowing adoption. On the employee side, many workers whose jobs are well-suited to telecommuting and whose managers would permit it, do not choose to telecommute for a variety of reasons and many who start telecommuting, stop within about a year. Nevertheless, data available suggests that nationally about 11 million or 9 percent of the workforce telecommute at least once a month.

Pat Mokhtarian (UC/Davis) has conducted a study for the Commission to attempt to identify the extent telecommuting reduces vehicle miles traveled (VMT) and energy use.<sup>1</sup> A number of studies have established the short-term transportation benefits of telecommuting at the disaggregate level: vehicle miles traveled are substantially reduced for those who telecommute, for as long as they telecommute. The question is whether telecommuting is likely to provide a substantial contribution to reduce VMT and fuel use. Mokhtarian has suggested it will not in view of the relatively small amounts of telecommuting occurring today, the relatively slow growth that can be expected as the phenomenon matures, as attrition continues to occur and the likelihood of long-term indirect impacts (e.g. longer commutes) partly counteracting the short-term direct savings. In a previous study using a modeling approach, analysis by Mokhtarian suggested telecommuting eliminates at most 1 percent of total household vehicle miles traveled.<sup>2</sup>

#### **Assumptions and Methodology**

The present study using national VMT data found appropriate data are quite limited and the results were inconclusive. One possible conclusion of the study is that we can be 90 percent confident that telecommuting reduces VMT (by an amount as little as 0.34 percent), but not 95 percent confident that it does. An additional reduction of light duty fuel use by 0.34 percent

could yield fuel savings of 56 million gallons in 2010 and 65 million gallons in 2020. The base case is based on actual fuel use and includes the effects of current levels of telecommuting. Based on present information, telecommuting appears to offer only very minimal potential to reduce VMT and energy use.

## Results

	Annual Petroleum Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	56	65	N/A
Reduction From Base Case Demand (percent)	0.3	0.3	N/A

\*Gasoline displacement.

## Key Drivers and Uncertainties

- Better data are needed for a more precise determination of the true impact of telecommuting on VMT.
- Disseminating case-study information on telecommuting successes may be an effective approach to motivate increased telecommuting.

---

<sup>1</sup> Pat Mokhtarian, Impacts of the Telecommuting on Vehicle-Miles Traveled: A Nationwide Time Series Analysis. UC Davis, December, 2001.

<sup>2</sup> Pat Mokhtarian, A Synthetic Approach to Estimating the Impacts of Telecommuting on Travel, Urban Studies, Vol. 35, No.2, 215-241, 1998.

## **Option 4D**

### **Reducing Speed Limits**

**(Analysis by Leigh Stamets)**

#### **Description**

As vehicles are less efficient at high speeds, enforcing reduced speed limits on state highways could reduce petroleum use. Appropriate action would need to be taken by the Governor or Legislature to implement this change.

#### **Background**

Increased California Highway Patrol enforcement would require increased spending authorization. Funding and resources would be required for new signage where current the speed limit exceeds 65 miles per hour (mph) or higher, as well as to notify motorists of the increased enforcement activity.

#### **Assumptions and Methodology**

Little data are available for speed distributions on California highways. Data for average speeds in the Los Angeles region suggest 8.9 percent of the vehicle miles traveled occurs at speeds from 57.5 to 62.5 mph and 13 percent at speeds from 62.5 to 67.5 mph.<sup>1</sup> Higher average speeds accounted for no additional vehicle miles traveled. Data from the Federal Highway Administration for 1988-1997 cars and light trucks show fuel economy declines by 3.1 percent going from 55 to 60 mph and 9.9 percent from 55 to 65 mph.<sup>2</sup> Applying these values to the above speed distribution results in potential fuel savings of 1.5 percent with speeds limited to 55 mph. These savings would be 258 million gallons in 2010, 294 million gallons in 2020, and 335 million gallons in 2030.

Costs of the measure would include modification of speed limit signs and enforcement of speed limit. Contingency planning analysis determined the program could be self-funding as penalty fees received from ticketed motorists would offset costs of the program.<sup>3</sup> Other direct costs would include time losses due to slower driving and benefits would include probable lower accidents rates.

#### **Results**

	<b>Annual Petroleum Reduction</b>		
	<b>2010</b>	<b>2020</b>	<b>2030</b>
Strategy Results (millions of gallons)*	258	294	335
Reduction From Base Case Demand (percent)	1.2	1.2	1.2

\*Gasoline displacement.

## Key Drivers and Uncertainties

- Probably little support for reduced speed limits.
- Present amount of travel at speeds above 70 mph that substantially affects fuel economy.
- Public acceptance is key to making speed limit strategy work.<sup>4</sup>

---

<sup>1</sup> Year 2000 Light and Medium Duty VMT by Speed Distribution, SCAG 2001 AQMP/2001 RTP, data received by ARB 7-19-01.

<sup>2</sup> Transportation Energy Data Book, Oak Ridge National Laboratory, Edition 20, October 2000, p 7-23.

<sup>3</sup> Energy Shortage Contingency Plan, Technical Appendix, California Energy Commission, March 1993, p T-24.

<sup>4</sup>Transportation Research Board Special Report 204: 55, A Decade of Experience, National Research Council, 1984.

## **Option 4E**

### **Voluntary Accelerated Vehicle Retirement**

**(Analysis by Leigh Stamets)**

#### **Description**

Voluntary Accelerated Vehicle Retirement (VAVR) programs provide incentives to scrap older light-duty vehicles that are responsible for high levels of emissions. This option involves the energy benefits that could be achieved from a VAVR program primarily conducted to reduce criteria air pollutant emissions.

#### **Background**

As the vehicle exhaust standards for criteria air pollutant emissions have become much more stringent and some older vehicles are extremely high-emitters of criteria pollutants, VAVR programs can contribute substantially to reducing criteria pollutant emissions.

VAVR programs will likely have limited effect on fuel use. The change in fuel use would depend on the change in the ratio of vehicle miles traveled (VMT) divided by miles per gallon (mpg). Limited analyses and data suggest little change in VMT or mpg.

EPA data indicate the average on-road fuel economy of light duty vehicles over the last 20 model years has been in the range of 20 to 22 mpg.<sup>1</sup> Commission analysis estimates the fleet average fuel economy of all light duty vehicles in California to be in this range with a value of 20.8 mpg.<sup>2</sup> DMV registration data suggest about 85 percent of the vehicles in the fleet are 20 years of age or less. The older vehicles average about 15 mpg.

In their analyses of the effect of VAVR programs in Southern California, both Sierra<sup>3</sup> and RAND<sup>4</sup> assumed the total number of miles traveled would not be altered by the VAVR program and the scrapped vehicles are replaced, on average, by the average vehicle remaining in the fleet. These assumptions would result in no change in energy use when scrapping vehicles less than 20 years old. With reduced use of vehicles over 20 years old, perhaps 6,000 miles per year, scrapping one of these vehicles today would save about 100 gallons of fuel annually.

Using the CALCARS vehicle choice model to analyze the effects of VAVR programs starting in 1999 for 75,000 vehicles annually in Southern California, Commission staff forecast a scrappage program would cause a slight increase, perhaps 0.5 percent, in gasoline use.<sup>5</sup> Although the model predicts the replacement vehicle would be slightly more efficient, the increase in fuel efficiency would not be enough to overcome the positive effect on VMT from a younger fleet, so gasoline use would increase.

As one example of the effect of a VAVR program, analysis of the 1990 Unocal program in the South Coast found 86 percent of the participants in the program were driving another vehicle.<sup>6</sup> In addition, 68 percent of the new cars had higher fuel economy and 82 percent of the cars were

driven the same or more miles per day than the cars they replaced. Data suggested a typical retired car had an average remaining life of 6 years.

### Assumptions and Methodology

Staff assumed accelerated scrappage of 150,000 vehicles annually statewide. Relying on the approach of RAND and Sierra using constant VMT, staff assumed in 2010, 10 percent of the VAVR retirements would be cars older than 1980 vintage. Staff also assumed the program would accelerate retirements by 6 years. Using the above value of 100 gallons of annual fuel savings per retirement of pre-1980 vehicles, 8 million gallons are saved in 2010. By 2020, staff assumed all retired cars would be post-1980 vintage. Retired and replacement cars would have essentially the same fuel economy based on the assumption of no fuel economy improvement in the base case. No fuel would be saved.

In the other approach staff relied on the CALCARS results, where VMT would increase about 0.5 percent statewide based on some replacement of retired cars by newer cars which are driven more as predicted by the model. With little or no difference in fuel economy, especially for post-1980 vehicles, between the retired and replacement vehicles, gasoline demand would also increase 0.5 percent, or a 0.4 percent increase in total gasoline and diesel demand.

The energy portion of the VAVR program has no cost as the program is being conducted and incentives are being given primarily for emission reductions.

### Results

	Annual Petroleum Reduction		
	2010	2020	2030
Strategy Results (millions of gallons)*	8 to - 86	0 to - 98	0 to -115
Reduction From Base Case Demand (percent)	0 to -0.4	0 to -0.4	0 to -0.4

\*Gasoline displacement.

### Key Drivers and Uncertainties

1. Appropriate incentives.
2. Change in VMT.

---

<sup>1</sup> U.S. Environmental Protection Agency, Light-Duty Automotive Technology and Fuel Economy Trends 1975 Through 2001, September 2001.

<sup>2</sup> California Energy Commission Staff Draft Report, Base Case Forecast of California Transportation Energy Demand, December 2001.

<sup>3</sup> Sierra Research, Vehicle Scrappage: An Alternative to More Stringent New Vehicle Standards in California, March 15, 1995.

<sup>4</sup> RAND, Fighting Air Pollution In Southern California by Scrapping Old Vehicles.

<sup>5</sup> California Energy Commission, Preliminary Staff Draft, Comparing the Effects of Two Accelerated Vehicle Retirement Programs Using a Behaviorally-Based Vehicle Choice Model, November 26, 1996.

<sup>6</sup> Fairbank, Bregman & Maullin, Final Summary Report on the Results of the Unocal Scrap Program Post-Participation Survey, March 22, 1991.

## **APPENDIX A CONSUMER SURPLUS**

Since it is not possible for sellers of automobiles (or most other goods) to isolate every buyer and charge the maximum he or she would be willing to pay, the purchase price of an auto will usually be less than the total benefit to the buyer. The difference between a consumer's maximum willingness to pay and the market price of a good is known as consumer surplus. Since consumer surplus is a part of the total benefit of vehicle ownership and use, changes in consumer surplus that result from implementation of new transportation measures must be considered in any cost-benefit analysis of these measures. The concept of consumer surplus is used extensively in economic analyses, primarily in studies that deal with consumer welfare.

### **Demand and Consumer Surplus**

To understand consumer surplus, the place to begin is with the concept of demand. The Law of Demand states that if a good is normal (that is, the demand for that good rises when income increases), the amount demanded of the good will fall when its price rises. Put another way, a normal good will have a downward sloping demand curve.

Below is given an example of an individual's demand for a normal good ("widgets") at various prices.

<b>Price (\$)</b>	<b>Amount Demanded</b>
8	0
7	1
6	2
5	3
4	4
3	5
2	6
1	7

At a price of \$8, the consumer will not buy any widgets, at \$7 he will buy one, and so on. Now suppose that the market price is \$5, which means that the individual will buy three widgets. However, as the demand schedule shows, he would have paid as much as \$7 for the first unit (i.e., the first unit has a value of \$7 for this consumer). The difference between the value of the first unit to the consumer, \$7, and what he actually pays, \$5, is a gain from trade, or consumer surplus, of \$2. Similarly, the second unit yields \$1 of surplus, for a total of \$3. Although not as tangible as a gift of \$3, this benefit is just as real. Total consumer surplus would rise if the going price of widgets dropped and fall if the price rose (e.g., a price of \$4 yields \$6 in surplus and a price of \$6 yields \$1). If a tax of \$1 were placed on this good when the price was \$5 (so that the price became \$6), consumer surplus would fall by \$2.

## Utility and Consumer Surplus

Economists associate a level of satisfaction, or utility, with the consumption of a good or service. A basic tenet underlying demand curves is that consumers maximize their utility when choosing goods and services, subject to market prices and income or wealth. This means that a consumer's demand curve for a product is the direct result of utility maximization. Using the example given above, utility maximization leads the consumer to demand two units when the price of widgets is \$6, to demand three units at \$5, and so on.

In order to model consumer preferences, the utility function is used. This function assigns a number to every possible consumption bundle (combination of goods and services) under consideration, so that more-preferred bundles are assigned higher numbers than less-preferred bundles. Demand for a good or service can then be derived from the utility function, maximized given prices and income or wealth.

In the CALCARS model, households choose vehicles based on the utility that they offer, where utility is a function of fuel cost per mile, performance, size class, etc. Since consumer surplus can be estimated from an individual's demand curve, and demand can be derived from a utility function, it follows that consumer surplus can be estimated directly from a utility function. This is the approach used in the CALCARS consumer surplus calculations.

## The Net Costs of Incentives and Taxes

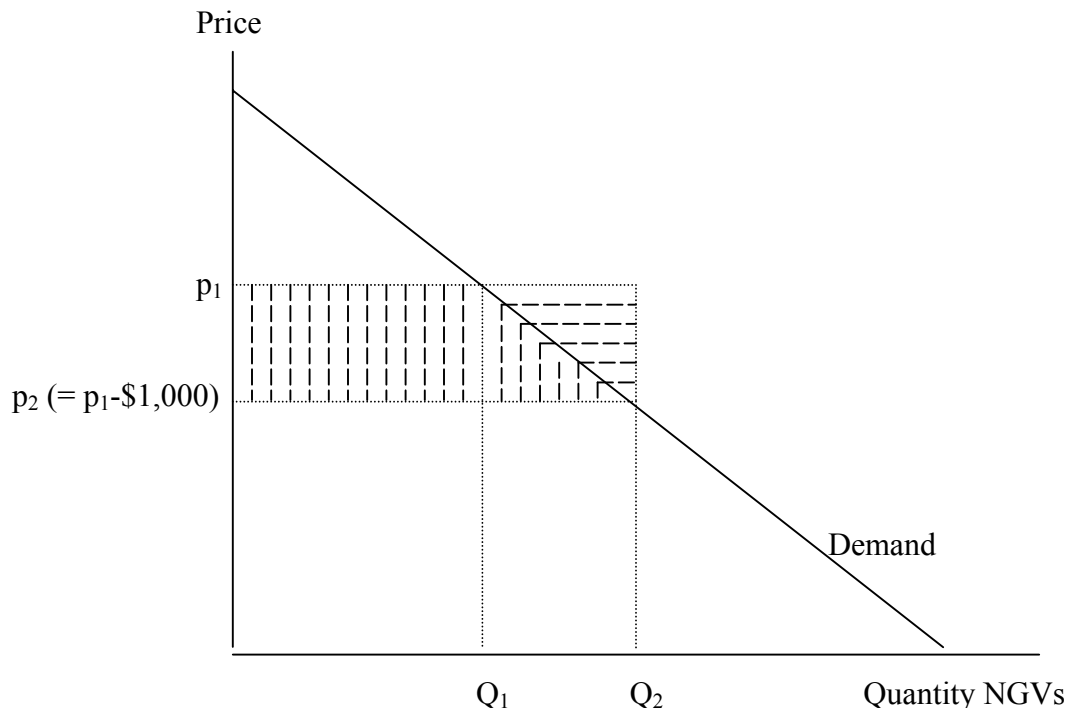
The following discussion illustrates the net costs imposed on society of both incentives and taxes. It should be noted that these results do not mean that taxes and incentives are never justifiable from a societal perspective. For example, subsidies may be justified in terms of accelerating the development of a new technology, and taxes may improve societal welfare if the good being taxed generates external (environmental) costs.

**Incentives:** If the government takes money from a taxpayer and gives it to someone else, there is no net effect on direct costs/benefits. However, if the government takes money from a taxpayer and gives it to someone else conditional on purchasing some product (i.e., an incentive), then there can be a net effect.

Suppose the government offers an incentive of \$1,000 to purchasers of natural gas vehicles (NGVs). This is shown in Figure A-1, assuming a linear demand.

$Q_1$  is the amount of NGVs purchased before any incentive, at price  $p_1$ .  $Q_2$  is the amount of vehicles purchased with the incentive. The cost of the incentive is  $\$1,000 \times Q_2$ . However, the benefits (the increase in consumer surplus going to buyers of NGVs) are only  $(\$1,000 \times Q_1) + (\$1,000 \times (Q_2 - Q_1)/2)$ , which are less than the costs. In the graph, the area shaded with vertical lines (the increase in consumer surplus) gives the benefits. The net cost of the incentive (known as the "deadweight" loss) is shown as the triangle shaded with horizontal lines.

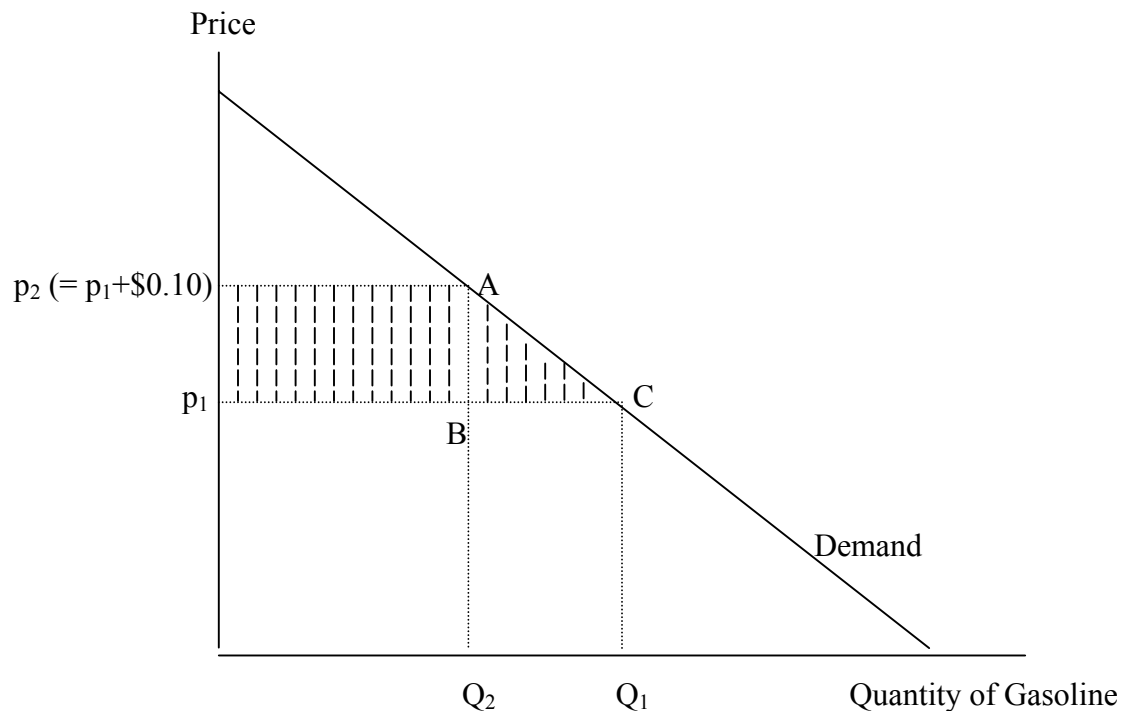
**Figure A-1. The Net Costs of an Incentive for Natural Gas Vehicles**



Intuitively, the reason that benefits are less than costs is that the benefit to buyers that would not have bought the NGVs without the incentive is less than \$1,000 per vehicle. For example, there may be a new vehicle purchaser who values a gasoline vehicle at \$600 more than a similar NGV so that, without any incentive, this buyer would choose the gasoline vehicle. If an incentive of \$1,000 were offered for the purchase of an NGV, our buyer would now choose the NGV, since the net benefits corresponding to this vehicle are now higher than those of the gasoline vehicle. However, the buyer is only \$400 better off than he would be with the gasoline vehicle (\$1,000-\$600). In other words, this transaction results in a net cost to society of \$600, since we have spent \$1,000 to yield a benefit of only \$400. The total net costs of this incentive come from all buyers who would require less than \$1,000 to switch. The only way that we could make the net costs of this incentive zero is if we could individualize the incentive--paying each person just what it would require for them to switch. Unfortunately, this would be almost impossible to do.

**Taxes:** The net cost to society of a tax (such as an excise tax on gasoline) is the difference between the loss in consumer surplus due to the tax and the tax revenue that is generated. Suppose that an excise tax of 10 cents is placed on the price of gasoline (or, more realistically, the excise tax is raised by 10 cents). Figure A-2 shows the result.

**Figure A-2. The Net Costs of a Gasoline Tax**



$Q_1$  is the amount of gasoline purchased before the tax, at price  $p_1$ .  $Q_2$  is the amount of gasoline purchased with the tax imposed, at the higher price  $p_2$ . The tax revenue generated is the amount  $(p_2 - p_1) \times Q_2$ , which would be considered a benefit to society. However, the cost of the tax--the loss in consumer surplus--is the entire shaded area shown in Figure A-2. Therefore, the tax imposes net costs on society (known as the “deadweight” loss), given by the triangle ABC. Intuitively, these costs are the value to vehicle owners of the reduced consumption of gasoline.

## **Appendix B**

### **Ethanol Demand and Supply Analysis**

#### **Demand**

Some of the options studied for petroleum displacement imply significant use of ethanol. The Ultimate E-85 FFV Market scenario in Option 2F represents an upper bound and implies the need for very large volumes of ethanol in the form of E-85 and decreasing volumes of California Reformulated Gasoline (CaRFG). As Fuel Flexible Vehicles (FFVs) are phased into use, we assume that inducements to consumers to use E-85 or another “FFV fuel” containing ethanol are sufficient to achieve high levels of ethanol consumption envisioned in this “ultimate” case.

To determine the feasibility that adequate ethanol can be obtained under a highest demand scenario, the Ultimate E-85 FFV market scenario of Option 2F is evaluated along with Option 2G which requires ethanol use at the E-10 level in gasoline vehicles. The options are interdependent, i.e., vehicles will operate on either E-85 or on E-10. While not likely, we assume that none of the other optional paths for petroleum reduction are adopted or implemented. Thus, the evaluation here represents the ultimate maximum conceivable demand for ethanol in California up to the year 2030 presuming that gasoline vehicles never use CaRFG containing more (or less) than 10 percent ethanol.

Table B-1 summarizes ethanol demand from the combination of E-10 and E-85 in 2010, 2020, and 2030 for FFV market penetrations assumed in Table 2F-4, Option F.

**Table B-1. High Case Ethanol Demand (billion gallons/year)**

<b>Fuel Type</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
E-10	1.60	0.99	0.43
E-85	1.61	11.20	20.83
<b>Total Ethanol Demand</b>	<b>3.21</b>	<b>12.19</b>	<b>21.26</b>

Table B-2 provides a second analysis corresponding to an “E-40” fuel containing 40 percent ethanol that may more realistically represent a future “FFV fuel”. This fuel would utilize refinery byproducts along with ethanol and other renewable or non-renewable (e.g. natural gas based) liquid fuels. This fuel is assumed to contain about 40 percent ethanol, refinery byproducts (e.g. rejected pentanes and other hydrocarbon blending components), other alcohols and/or co-solvents and would likely have production costs lower than that of E-85. In this analysis, we assume that ethers will never again be used in gasoline because of real or perceived negative health effects associated with groundwater contaminated by ethers. This FFV fuel (whether E-85 or E-40) is assumed to be distributed in same manner that gasoline is, i.e., through the then existing CaRFG infrastructure, including bulk transport by pipeline.

**Table B-2. Intermediate Case Ethanol Demand (billion gallons/year)**

<b>Fuel Type</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
E-10	1.60	0.99	0.43
E-40 (FFV “optimal” fuel)	0.76	5.27	9.80
<b>Total Ethanol Demand</b>	<b>2.36</b>	<b>6.26</b>	<b>10.23</b>

This latter case illustrates ethanol demand at about half of the requirements of the Ultimate Demand in 2020 and 2030 as would be expected, since FFVs represent an increasingly larger percent of the in-use vehicle fleet as time moves on. Another interpretation of Table B-2 is that it represents ethanol demand in the case where consumers purchase E-85 about half of the time while using CaRFG the rest of the time in their FFVs. This fueling practice in effect constitutes an E-40 (actually, 42.5) fuel on average over the lifetime of the vehicle.<sup>1</sup>

It is worth noting that unlike dedicated alternative fuel vehicles, high penetration of FFVs in the California vehicle fleet would likely mitigate common supply and demand issues surrounding availability of alternative fuel since these vehicles can operate on gasoline, the alternative fuel or any combination of the two (down to 15 percent gasoline), at any time. Thus, the vehicle technology restores control and flexibility to suppliers and distributors of liquid fuels such that they can produce, deliver and price gasoline and alternative fuels consistent with availability and the cost of blending components needed to produce them. The expectation is that, in the longer term (2020-2030), liquid transportation fuel prices will be lower given a large FFV fleet as opposed to a gasoline only and/or dedicated alternative fuel only vehicle fleet. Thus, while the ultimate demand scenario requiring 21.26 billion GPY ethanol in 2030 to make E-85 for full-time use in FFVs is conceivable, a more likely upper bound is 10.23 billion GPY (the Intermediate Case Ethanol Demand in Option 2F) where California refiners would have more reason and options in blending low cost fuels.

## **Supply**

Supplies of ethanol for use in California are assumed to come from three major sources. We assume the following:

1. In the near term, the Midwest states will continue to provide the majority of ethanol used in CaRFG3 and in FFVs.
2. California will create its own ethanol production industry that will significantly decrease the otherwise required level of imported ethanol in the 2010 to 2030 timeframe.
3. Foreign ethanol will have a role to play when U.S. domestic supplies of ethanol are tight and prices are high.

Each of these supply sources is covered in more detail in the following paragraphs.

## Midwest Sources of Ethanol

It is assumed that the federal Renewable Fuel Standard (RFS) currently under discussion in Congress will be passed into law under new federal energy programs and policies, and that MTBE will be banned nationwide. The RFS will require 5 billion GPY ethanol production capacity by 2013 and we assume that most of this volume will be produced in the Midwest with some contributions from PADDs 1, 3 and 4. A separate DOE report projects a growth in renewable fuels use from 1.9 billion today to 8.8 billion GPY in 2016. Using this basic growth assumption that 85 percent ethanol use and 15 percent other renewable fuel use, this translates into new ethanol production capacity of about 390 million gallons per year or about 10 new facilities, each producing 40 million gallons of ethanol. We assume that this growth rate is constant through 2030 yielding conventional grain based ethanol volumes as shown in Table B-3. We start with a capacity of 2.3 billion GPY and discount it 15 percent for beverage and industrial ethanol markets in 2002. This growth in capacity is only half of what is projected over the next several years in the U.S. to meet anticipated demand for ethanol as a result of MTBE phase-out needs in California, thus, it is somewhat conservative relative to near term growth rates in ethanol production.

**Table B-3. Midwest Fuel Ethanol Production Capacity (Billion GPY)**

Source of Ethanol	2010	2020	2030
Conventional grains	5.47	9.37	13.27
Cellulose (non-Calif/PADD5)	0.90	5.0	9.00
<b>Total supply</b>	<b>6.39</b>	<b>14.37</b>	<b>22.27</b>

Also included in Table B-3 is cellulose-based ethanol production, based on the conversion of corn stover, wheat straw, rice straw, energy crops, sugar cane field residues and other waste biomass resources. We have assumed that DOE RD & D combined with partnerships with industry will stimulate growth of cellulose-based ethanol substantially by 2020, and that cellulose-based ethanol reaches 5.0 billion gallons by 2020. This volume is consistent with estimated volume (excluding the California volume) in the DOE ethanol infrastructure study performed by DAI.<sup>2</sup> A higher than 10 billion GPY volume case was not examined by DAI, thus, staff chose the DAI growth rate (PADD 5 excluded) of 4 billion gallons of cellulose-based ethanol over 10 years to establish the 2030 value of 9 billion GPY cellulose-based ethanol production in all states excepting California.

## California Ethanol Supply

It is assumed that California will become an ethanol producing state in the very near future by creating an incentive program for ethanol production based on the success of programs initiated during the 1990s in Midwest and in other states. More importantly, California would be totally dependent on imported ethanol if it did not create an industry to meet some portion of the anticipated demand in-state demand for ethanol. Accordingly, this analysis assumes that AB 1728 (Costa, 2002) is signed into law thus creating an incentive program that would pay from 20 to 40 cents per gallon for a portion of ethanol production in in-state facilities. It is further assumed that California facilities will supply 50 percent of California's ethanol demand for in 2010, consistent with the legislative goal established in AB 1728 to meet half the ethanol demand using in-state facilities by 2010.

Before 2010, it is assumed that in-state ethanol will be derived primarily from conventional starch and sugar resources primarily (corn, barely, sugar cane, sorghum, sugar beets and others). Several facilities will begin to integrate cellulose processing facilities to increase the capacity of these ethanol plants by utilizing cellulose-based biomass wastes associated with the conventional starch and sugar feed stocks and other biomass wastes.

By 2020 cellulose-based ethanol from forest, agricultural and urban wastes becomes a significant source of the in-state ethanol production (carrying on through 2030) based on advances in conversion technology and large-scale commercial implementation. It is assumed that cellulose-based ethanol developments will largely occur in integrated fashion with conventional ethanol production as a cost cutting approach by California facilities to remain competitive with imported ethanol from the Midwest, Pacific Northwest, and other regions of the country.

It is assumed that 1.25 million acres of irrigated agricultural land is available for conventional grains such as sugar cane, barley, wheat, sugar beets, sorghum and other high starch and sugar sources in 2010. This acreage (about 10 percent of croplands) represents a conservative estimate of land available on which historical but now uneconomic crops were raised. Table B-4 summarizes estimated production capacity based on several additional assumptions. Sugar cane, sugar beets and sorghum are grown in the Imperial Valley on 250,000 acres devoted to these crops by 2030. The remaining one million acres in corn and other grains and energy crops are assumed to yield 500 gallons ethanol/acre annually, with growth to 3 million acres by 2030 and improved yield at 600 gallons ethanol/acre. California's forestry, agricultural, and urban cellulosic wastes are utilized at 5 percent, 50 percent and 90 percent of the long-term resource base for ethanol production in 2010, 2020, and 2030 respectively.

**Table B-4. California Ethanol Production Capacity Compared with AB 1728 Production Goals (Billion GPY)**

<b>Source of Ethanol</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
Sugar Cane (+field trash and residues)	0.40	0.40	0.60
Grains (corn, barley, wheat, sorghum)	0.50	1.1	1.8
Waste Biomass (cellulose)	0.19	1.9	3.51
<b>Total Supply</b>	<b>1.09</b>	<b>3.4</b>	<b>5.91</b>
50% of high demand case goal	<b>1.6</b>	<b>6.1</b>	<b>10.65</b>
50 % intermediate demand goal	<b>1.18</b>	<b>3.13</b>	<b>5.12</b>

Table B-4 illustrates that it is difficult to meet the high demand case ethanol production goal and California would need to look towards importing about 2.1 billion GPY of ethanol in 2010, 8.8 billion GPY in 2020 and 15.39 billion gallons in 2030. The latter requirement is about 70 percent of projected Midwest (and other PADD) supplies as seen in Table B-3, however, and foreign-based ethanol needs to be considered.

## Out-of-Country Ethanol Supplies

In this analysis, it is assumed that the existing federal import tariff of 54 cents per gallon on foreign produced ethanol is retained through 2020, thus precluding importation of low cost foreign ethanol that would undercut the development of, and prevent emergence of an in-state ethanol industry from the present time to 2020. However, we assume that tariff free ethanol does flow through the Caribbean up to volumes allowed (7 percent of the previous year's U.S. domestic ethanol production). This amounts to additional ethanol volume in 2010, 2020 and 2030 of 0.470, 0.940 and 1.428 billion GPY respectively. We assume that all the volume would come to California since CaRFG is assumed to be the highest value "boutique" fuel market in the U.S. This volume is shown in Table B-5.

Since Brazil currently has in excess of one billion GPY idled ethanol production capacity, but at times capacity has been fully utilized, we assume that by design, Brazil will plant additional sugar cane and construct additional ethanol production/sugar processing facilities in view of growing markets in the U.S. It is further assumed that significant volumes of ethanol start to flow to the U.S. around 2020 when international agreements could be in place abolishing all protective trade barriers to the marketing of ethanol worldwide. Ethanol from Brazil is assumed to be imported at 200 million GPY in 2010 and stepping up in 2020 with trade normalization. These are conservative growth estimates given Brazil's still vast underdeveloped sugar-cane growing regions.

We assume an additional flow of ethanol from Canada and Mexico under the assumption that long-term fuel ethanol markets in California are lucrative under NAFTA favored trade status.

**Table B-5. Ethanol Supply from all Sources Excluding U.S. Domestic Supplies (Billion GPY)**

<b>California</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
Sugar Cane (+field trash and residues)	0.20	0.40	0.60
Grains (corn, barley, wheat, sorghum)	0.50	1.1	1.8
Waste Biomass (cellulose-based)	0.39	1.9	3.51
Caribbean (CBI) ethanol	0.2	0.94	1.28
Brazilian	0.2	0.8	1.5
NAFTA partners	0.2	0.5	0.8
<b>Total Supply</b>	<b>1.69</b>	<b>5.64</b>	<b>9.49</b>
50 % of high demand case goal	<b>1.6</b>	<b>6.1</b>	<b>10.65</b>
50 % intermediate demand goal	<b>1.18</b>	<b>3.13</b>	<b>5.12</b>

With these modest contributions to supply from foreign sources, the balance of ethanol supply needed from the Midwest and other states under both California demand scenarios now appears to be:

**Table B-6. Implied Ethanol supply from Midwest and other States (billion GPY)**

<b>Source of Ethanol</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>
All foreign	0.70	2.24	3.58
California conventional crops	0.70	1.5	2.4
California waste biomass	0.39	1.9	3.51
<b>subtotal</b>	<b>1.69</b>	<b>5.64</b>	<b>9.49</b>
<b>Demand scenarios</b>			
High demand (ultimate) volume	<b>3.21</b>	<b>12.19</b>	<b>21.26</b>
Intermediate demand volume	<b>2.36</b>	<b>6.26</b>	<b>10.23</b>
<b>U.S. Domestic ethanol</b>			
Required supply (ultimate scenario)	<b>1.52</b>	<b>6.55</b>	<b>11.77</b>
Required supply (intermediate scenario)	<b>0.67</b>	<b>0.62</b>	<b>0.74</b>
<b>U.S. Domestic supply</b> (from Table B-3)	<b>6.39</b>	<b>14.37</b>	<b>22.27</b>

Table B-6 shows that under the high demand case where many FFVs use E-85 all the time, and gasoline vehicles use a CaRFG E-10 fuel all the time, required domestic ethanol volumes are 23, 46 and 53 percent of the projected U.S. supply of ethanol in 2010, 2020, and 2030 respectively. However, at half-time use of E-85 by FFV drivers or if an “optimal” E-40 fuel is developed with full time E-10 CaRFG use in the remaining California light duty vehicle gasoline fleet, then non-California U.S. domestic ethanol drops to 10, 4.3 and 3.3 percent of available supplies in 2010, 2020, and 2030 respectively.

The intermediate scenario domestic supply volume could be higher in 2020 and 2030 presuming a balance between imported ethanol and Midwest ethanol shipped to California. This may occur as a result of international diplomacy to maintain a sense of “fair game” between domestic and foreign suppliers of fuel ethanol. In this case, foreign and U.S. domestic ethanol producers would supply 1.43 billion GPY each, which corresponds to 10 percent of the estimated 14.37 billion GPY domestic supply. In 2030, this matching supply approach would yield 2.16 billion GPY each, which is also 10 percent of the projected domestic supply of 22.27 billion GPY. This 10 percent is a fair representation of California’s current gasoline consumption as a percent of national consumption.

## **Conclusion**

The intermediate ethanol demand scenario examined here appears workable from an ethanol supply perspective. An “ultimate” case FFV penetration scenario is supportable under this intermediate demand for ethanol at use rates corresponding to half-time use of E-85 or full time use of an “optimal” FFV fuel containing about 40 percent ethanol. This can occur simultaneously with the gasoline fleet operating full-time on an E-10 version of CaRFG. Under this supply analysis, the full-time use of E-85 in a case where all vehicles sold in California are FFVs by 2017 does not appear feasible because it would require a very large fraction of the total projected U.S. ethanol supply developed under this analysis. Some analysts argue, however, that far greater supplies of ethanol can be produced from domestic resources including energy crops grown on marginal or underutilized lands.

The aggressive use of ethanol in the intermediate demand scenario requires rapid build up of in-state ethanol supplies. By 2020, about 85 ethanol production facilities producing 40 million GPY each would be required. In 2030, 148 ethanol plants would be required. These plants would be capable of supplying half of California's ethanol needs under the intermediate demand "bounding" case of 6.26 billion GPY ethanol in 2020 and 10.23 billion GPY ethanol in 2030. In 2030, 90 percent of California's annually available waste-biomass resources would be converted to ethanol supplying 60 percent of the in-state ethanol. The remaining 40 percent would come from conventional grains, sugar and starch sources using commercially available conversion technology.

---

<sup>1</sup> A fuel containing around 40 percent ethanol could be an "optimal" FFV fuel. An example of such a fuel can be found in an EPACT designated "substantially not petroleum" i.e. alternative fuel known as P-series (Federal Register, Vol. 64, No. 94, pp. 26822- 26829, May 17, 1999). Replicate FTP tests of this fuel in an FFV have illustrated the potential of carefully engineered fuels to provide lower emissions when compared to E-85, conventional, and reformulated gasoline, as well as extended vehicle range (relative to E-85), comparable gasoline (energy) equivalent fuel economy in addition to substantial petroleum displacement.

<sup>2</sup> "Infrastructure Requirements For An Expanded Fuel Ethanol Industry", Downstream Alternatives Inc., 2002.